Annual Review 2008

U.S. Army Research Laboratory


Many Minds
Many Capabilities
Single Focus on the Soldier
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AIRBORNE

From the Director

An Interview With
John M. Miller, Director of the U.S. Army Research Laboratory

Providing new or enhanced capabilities for Soldiers dictates the ARL's research program content, recruitment and development of human capital, investments in technical infrastructure and refinement of ARL's business processes. In this interview, the ARL Director, John M. Miller, discusses ARL's significant accomplishments, challenges it faces in the future and a new business process that will lead to enhanced portfolio management.

Q Looking back over the last year, what would you like to highlight as ARL's more significant accomplishments or initiatives?

A This past year, the ARL has had a number of significant accomplishments in support of our Soldiers in the field. For example, for PM MRAP, ARL developed several armor solutions to defeat EFP threats that resulted in substantial weight reductions while still maximizing both crew protection and vehicle sustainability. We've also delivered prototypes for improved IED protection; demonstrated an ability to detect small UAV threat systems; helped our medical partners by providing them with a better understanding of weapons effects: and provided improved and customized English to Arabic language and text translation capabilities.

While Current Operations support is of utmost importance, it tends to focus the laboratory's research on near and mid-term problems. We cannot forget that our primary mission is to maintain technology superiority on the future battlefield. To ensure we don't lose this future focus, we have established a number of critically important forward-looking areas of research to include: Advanced Computing, Bioscience, Materials, Network, Neuroscience, Power and Energy, Autonomous Systems, and System of Systems Analysis. Within

each area, there are one or more Strategic Technology Initiatives (STIs). These STIs are high risk research efforts, normally five years in length, with the potential for radical, game changing advancements in our science, technology, and analysis capabilities. Successful STIs will not only create new and superior capabilities for our Soldiers, they will provide the foundation for a world class ARL of the future.

Q. What do you see as the biggest challenges ARL faces in the future?

A. There are two challenges that ARL will continue to face in the future: 1) finding, recruiting, and maintaining a quality workforce, and 2) maintaining world-class facilities. Without both we do not have a world-class ARL.

First, let's talk about our workforce. ARL, like other research organizations, has to deal with normal attrition losses. I look at these losses as opportunities for us to continually adjust our skills mix to accommodate a changing technology environment. An example of a new area of research that can provide significant new capabilities or solutions is bioscience. Several years ago we did not have a bioscientist on staff, but today we have seven and expect to add more. We work closely with our university partners to attract the brightest they have to offer and maintain a strong outreach and Post Doc program to identify other outstanding S&E candidates. Once hired, we provide challenging research projects, early career leadership opportunities, world-class research facilities, and advancement opportunities to retain and develop our workforce. As a result, we are reinventing our workforce to position ourselves for the future in many areas of importance. Besides bioscience, we are building intellectual capital in human dimension, neuroscience, network science, and system of systems modeling and simulation.

Second, maintaining world-class facilities: We cannot recruit the best and brightest for ARL if we cannot provide commensurate research facilities. Since major construction funding is very limited, we have allocated mission funding for mission unique facilities and equipment and have worked with our Customers to capitalize on their investments to provide others. We set aside five percent of our total core mission funding for facilities and equipment upgrades. In FY08, that allowed us to fund over $25 million for numerous infrastructure improvements and equipment purchases. Three of those infrastructure projects used the new Congressional authority allowing Laboratory Directors to use up to $2 million of mission dollars to fund construction projects. The three were an addition to the EMVAF at WSMR, a new research facility for VTD personnel moving to APG, and a new Soldier performance research facility at APG. I continually look for opportunities to fund enhancements to our research facilities to ensure the ARL continues to have the technical infrastructure necessary to provide state-of-the-art technologies and capabilities in support of the Soldier.

Q. What can you tell us about the new technology integration program planning and execution model?

A. The technology integration program business process is an initiative established by RDECOM and represents a new business model for the Command. It takes the Command from an organizational centric model to a technology portfolio and system domain centric model. It provides a structured way for system and platform needs to be expressed in terms of capability requirements that can be translated into technology focus areas. This process will result in better communication between and among the requirements generators, the PEOs/PMs , the RDECs, and the ARL. This improved communication will lead to less duplication of effort, identification of research areas that are not being adequately addressed, and a better focus on high priority research. Much progress has been made, but we all have more work to do. I'm dedicated to making this process work, and in fact, I've changed the next ARL Program Formulation Workshop to be an RDECOM Technology Planning Workshop that will be organized by technology and domain areas. The fine tuning of this new business model and its full implementation will take sometime but, in the long run, it will prove to be an invaluable tool for the RDECOM to manage its research and development portfolio and to actively support the Chief of Staff of the Army's direction to take an enterprise approach to all we do.

Overview

The U.S. Army Research Laboratory (ARL) of the U.S. Army Research, Development and Engineering Command (RDECOM) is the Army's corporate, or central, laboratory. Its diverse assortment of unique facilities and dedicated workforce of government and private sector partners make up the largest source of world-class integrated research and analysis in the Army.

By combining its in-house technical expertise with those from academic and industry partners, ARL is able to maximize each dollar invested to provide the best technologies for our Soldiers. ARL's program consists of basic and applied research (6.1 and 6.2) and survivability/lethality and human factors analysis (6.6). ARL also applies the extensive research and analysis tools developed in its direct mission program to support ongoing development and acquisition programs in the Army Research, Development, and Engineering Centers (RDECs), Program Executive Offices (PEOs)/Program Manager (PM) Offices, and Industry. ARL has consistently provided the enabling technologies in many of the Army's most important weapons systems.

Technology and analysis products are moved into RDECOM RDECs and to other Army, Department of Defense (DoD), government, and industry customers. The Army relies on ARL to provide the critical links between the scientific and military communities. The Laboratory must marshal internal and external science and technology assets to fulfill the requirements defined by or requested by the Soldier. Equally important, the Laboratory must assist the Army user in understanding the implications of technology on doctrine and in defining future needs and opportunities.

Mission

The mission of ARL is to "Provide the underpinning science, technology, and analysis that enable full-spectrum operations." Within ARL we have teams working in partnership with the RDECs, Rapid Equip Force (REF), Joint Improvised Explosive Device Defeat Organization (JIEDDO), and others on the following tasks: current operational technical challenges facing Soldiers in Iraq (OIF – Operation Iraqi Freedom) and Afghanistan (OEF – Operation Enduring Freedom), maturing and transitioning technologies in the two to five-year timeframe for existing systems and the Future Combat Systems (FCS), and generating scientific discoveries that will provide the foundation for Soldier capabilities 15-20 years in the future.

Our mission statement is simple to state, but complex and difficult to execute considering the dissimilarity in urgencies of need across our customer base. Our team members understand our mission and they are proud of the contributions they are making for our Soldiers. Providing new or enhanced capabilities for our Soldiers dictates our research program content, recruitment and development of human capital, investments in technical infrastructure, and refinement of our business processes.

Vision

ARL's vision is articulated in a theme statement with three integral elements. It is used to guide organizational alignment and provide a comprehensive framework for critical review of our investments in research programs, technical infrastructure, and workforce development. Performance standards at all levels reflect the focus of each employee on achieving the goals.

The theme statement is: Many minds, many capabilities, single focus on the Soldier.

The elements are:

Acknowledged for scientific, technical, and analytic excellence.

ARL's workforce must continue to be comprised of top-flight, highly-productive scientists and engineers (S&Es) if we expect top-tier research organizations to interact and collaborate with us. Our interaction with quality researchers in the private sector provides the Army with invaluable opportunities to leverage the investment of others and to focus available intellectual talent on the Army's technical challenges. Those interactions are critical to our mission success and will only be possible if the greater research and analysis communities see us as peers. To accomplish this element, we must: continue to attract, develop, and retain the highest caliber technical talent; refresh and enhance our technical infrastructure; and increase the visibility of our research and staff in the private sector through publications and interaction in professional technical societies.

Recognized as the bridge between the Nation's S&T communities and the Army.

We envision ourselves as the bridge between these two groups providing the critical linkage to enable new technological capabilities to be provided to Soldiers. To achieve this, ARL must be trusted by both the private sector R&D community and the Army's technology users. ARL must be objective, possess a high level of integrity, and exhibit a high degree of technical competence. These traits are a prerequisite to being the organization of choice for the private sector to come to for assistance in transition or maturation of S&T for the Army; they are also required if Warfighters are to trust us to deliver the correct solutions in response to their technology needs. This dual trust and understanding enables us to couple the right sets of technologies to meet the right set of Soldiers' needs.

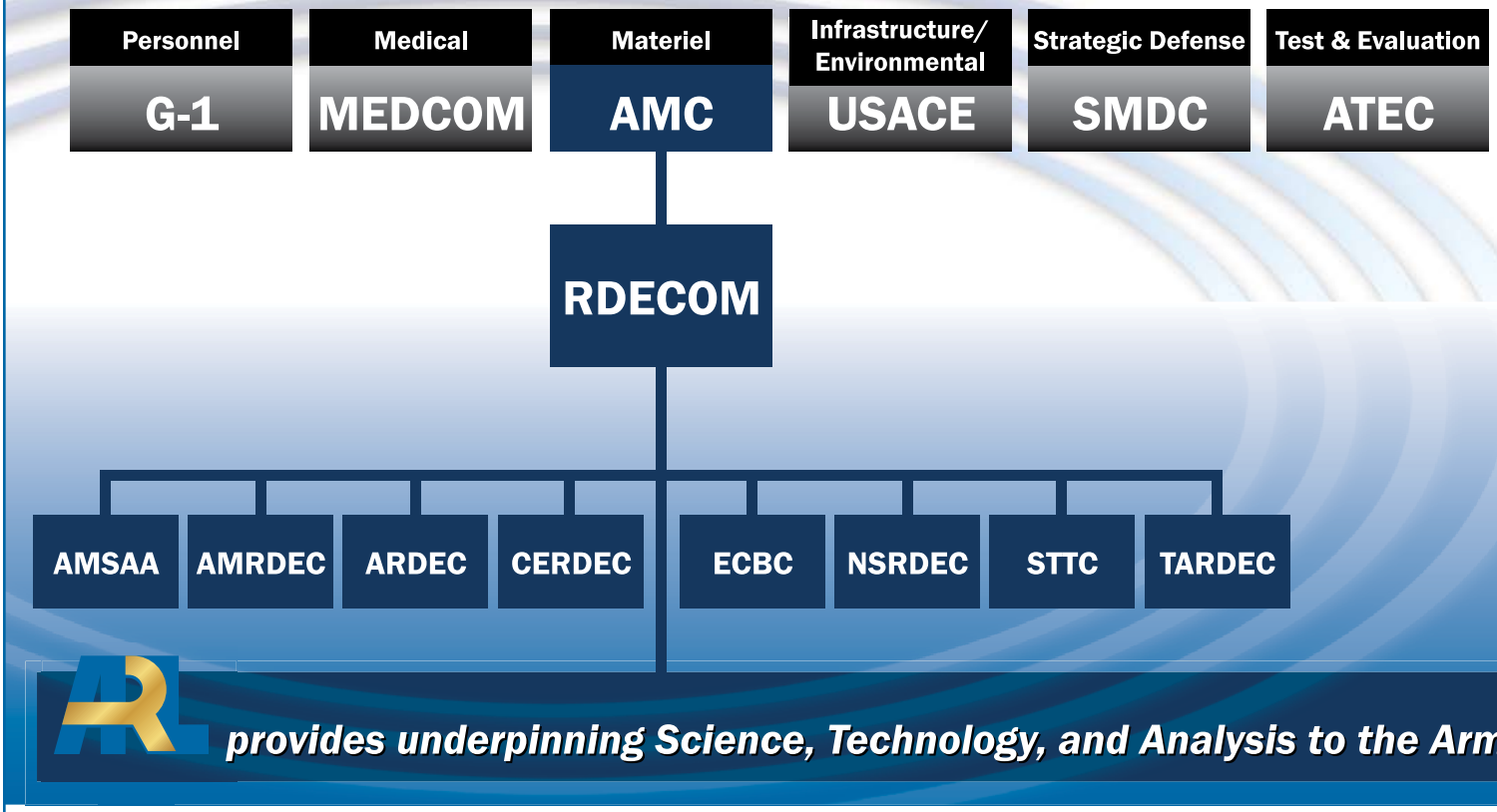
To accomplish this vision element we must: expand and refine partnerships with the private sector in research areas of interest; continue and expand rotational and developmental assignments of staff with both the private sector and other Army organizations; and continue to refine our internal and external knowledge sharing and communications processes.

Leader in providing innovative solutions for the current and future Army.

The strengths of our results-oriented workforce are the key to this vision element. Their inquisitiveness, the desire to tackle the toughest technical challenges, and focus on providing capabilities for Soldiers is unparalleled. Key to achieving this element are our workforce's abilities to generate, mature, and integrate technologies and the ability to establish and maintain the operational partnerships required to transition or transfer those technologies to the Soldier. To achieve this element of the vision we must: develop relevant and innovative solutions that can transition into capabilities for our Soldiers; continue to meet our reimbursable customer's technology needs; and increase external communications focused on the achievements of ARL and its research partners.

Organizational Role

ARL is a subordinate organization of the U.S. Army Research, Development and Engineering Command. We are a $1.9 billion a year organization that provides the underpinning basic and applied research for the Army's RDECs, and supports the efforts of a wide variety of customers ranging from the Army's Life Cycle Management Commands, our sister Services, DoD and other government agencies. Of the total revenue received in FY08, over 60 percent ($1.15 billion) came from ARL customers. Through this partnership with academia and industry, ARL also leverages several billion additional dollars of research.



ARL Technical Assessment Board

Since 1996, ARL has had a relationship with the National Research Council, of the National Academy of Sciences, whose mission is to improve government decision making and public policy, increase public education and understanding, and promote the acquisition and dissemination of knowledge in matters involving science, engineering, technology, and health.

The work of the NRC is made possible by 6,000 of the world's top scientists, engineers, and other professionals who volunteer their time without compensation to serve on committees and participate in activities.

As part of this relationship with the NRC, ARL has in place a Technical Assessment Board. The charge of this Board is to provide biennial assessments of the scientific and technical quality of ARL. These assessments include the development of findings and recommendations related to the quality of ARL's research, development, and analysis programs. We use their input to ensure our work is at the leading edge.

Board Members

Robert W. Brodersen
Chair
Professor, Department
of Electrical Engineering
and Computer Science
University of California, Berkeley

Kenneth L. Reifsnider
Educational Foundation
University Professor
of Mechanical Engineering
and Director,
Solid Oxide Fuel Cell Program
University of South Carolina

Don B. Chaffin
Richard G. Snyder
Distinguished University
Professor Emeritus
Industrial and Operations
Engineering
and Biomedical Engineering
University of Michigan

John C. Sommerer
Director of Science
and Technology
Chief Technology Officer
Johns Hopkins University,
Applied Physics Laboratory
Johns Hopkins University

Peter Kogge
Professor and Associate Dean
of Engineering for Research
College of Engineering
University of Notre Dame

Dwight C. Streit
Vice President
Northrop Grumman
Space Technology
Northrop Grumman Corporation

Key Locations

ARL has six primary sites: Adelphi, Md.;
Aberdeen Proving Ground, Md.;
White Sands Missile Range, N.M.;
Raleigh-Durham, N.C.; Langley, Va.; and Glenn, Ohio.

Electromagnetic Vulnerability Assessment Facility

The new facility addresses the complete electromagnetic threat being encountered in theater and anticipated for the Future Force.

Novel Energetics Research Facility

This facility contains a processing complex with energetics processing and manufacturing labs, an explosives casting lab, and it also has explosives x-ray capability.

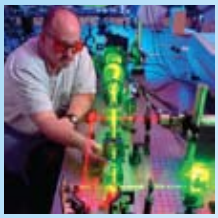
Shooting Simulator

An indoor small arms shooting performance simulator with a high-speed weapon tracking system that provides real-time continuous weapon aim point data.

Robotics Research Facility

This 13-acre course is used for unmanned vehicles and indirect driving studies. Driving paths include straightaways, slaloms, tight turns, and straight and broad paths in which obstacles such as logs and rocks must be avoided.

Laser Optics Testbed



This laboratory is equipped to support sophisticated investigations in adaptive and nonlinear optics, advanced imaging and image processing, and laser communications for ground-to-ground applications.

Pulse Power Facility

This facility provides a full-scale test bed for development, evaluation and demonstration of continuous power components.

Mobility/Portability Research Facility

The Army standard for measuring the effects of various equipment configurations and loads on Soldier mobility and physiological performance.

Vertical Impulse Measurement Facility

Facility for measuring accurately the combined debris and blast impulse produced in landmine detonations. Data are used to validate models and develop technologies for improved survivability of future lightweight tactical and combat vehicles.

Tactical Environment Simulation Facility

This facility integrates, under one roof, the Omni-Directional Treadmill (ODT) into virtual visual and auditory environments to enable laboratory controlled investigations.

Rodman Materials Research Laboratory

The Rodman has nearly 300,000 sq. ft. of laboratories that enable the pursuit of disruptive and challenging research and characterization in advanced materials technologies for potential applications in Army weapon systems.

Transonic Experimental Research Facility

Among other things, this facility evaluates aerodynamics and fluid dynamics of projectiles, smart munitions systems, and sub-munitions dispense systems.

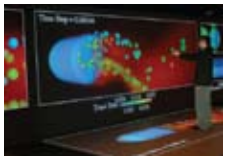
Zahl Physical Sciences Laboratory

The Zahl's cornerstone is its clean room. The lab enables basic and applied research and analysis in nanobiotechnologies; flexible electronics; advanced specialty electronics material growth; nonlinear material research and characterization; and power electronics.

Airbase Experimental Facility #6

This modern, centralized complex provides analysts, program managers, and decision makers with experimental data that addresses the SLV of air and ground combat systems.

MSRC & Scientific Visualization Facility



This facility features state-of-the-art scalable parallel architectures and large vector-parallel systems supporting both classified/unclassified missions throughout the DoD's RDT&E community.

Clean Rooms

This facility features a 10,000 sq. ft. class 100 and 4,200 sq. ft. class 10 clean-room device processing facility.

The Army Research Laboratory is the RDECOM lead agency for planning and executing research opportunities with academia. ARL has a number of complementary mechanisms for academic partnering, ranging from single investigator grants with individual university faculty, to large centers with groups and consortia, to direct collaborations between university research personnel and ARL in-house scientists, engineers and analysts.

In addition to these in-house facilities, ARL is actively engaged in funding research with over 250 universities and colleges located in all 50 states.

Workforce

ARL accomplishes its mission through the work of a highly educated and trained technical and support staff of 1,930 individuals. Of the 1,930 employees, 1,279 are classified as Scientific and Engineering (S&E), 886 of whom hold advanced degrees.

An organization is only as strong as the summation of the skills, expertise, and dedication of its workforce. ARL understands that our intellectual capital is our most critical resource. All research staffing decisions include a critical evaluation regarding generation or continuance of an internal capability vice reliance on external research partners and collaborators. Our goal continues to be a preeminent, multi-disciplinary, adaptive, and learning ARL team capable of meeting the challenges associated with the Soldier's technology requirements.

ARL recruits for and fills positions with the highest caliber applicants. Our interaction with ARL's network of research partners provides the opportunity to interact with graduate students and post-docs with the required expertise from which to recruit and our Personnel Demonstration Project allows starting pay to be negotiated in a competitive range.

1,279 Scientific & Engineering Employees

282	Electrical/Electronics Engineers
196	Physicists/Physical Scientists
175	Mechanical Engineers
145	Computer Scientists/Engineers
92	General/Industrial Engineers
86	Chemical Engineers/Chemists
67	Materials Engineers/Metallurgists
55	Engineering Psychologists
54	Operations Research Analysts
40	Mathematicians/Statisticians
36	Aerospace Engineers
19	Meteorologists
8	Biologists
5	Neuroscientists
5	Ceramic Engineers
14	Other E&S
239	E&S Technicians

ARL's technical staff must be highly skilled to accomplish our mission and our leadership stresses the importance of advanced technical degrees. In FY08, the ARL scientific and engineering staff was composed of 452 (35 percent) doctorates, 434 (34 percent) Master of Science degrees, and 393 (31 percent) Bachelor of Science degrees.

Key performance indicators for quality of the research staff include metrics reflecting the attitudes and technical opinions of the external research community essential for achieving the first element of our vision. For FY08, ARL performed exceptionally in the number of presentations/proceedings (1,044), refereed journal articles (268), technical reports (462), books published (5), chapters of books written (29), patents awarded (34), and invited talks (45). The ARL staff holds 557 memberships in professional organizations and societies; in those organizations there are 57 ARL scientists and engineers who are Fellows, and 49 of our scientists and engineers hold prestigious posts.

The strength of ARL truly lies in its intellectual diversity. Through focused recruiting efforts, we attract scientists and engineers from a large number of academic institutions worldwide. As a result of these efforts, ARL hired 99 new scientists and engineers in FY08 including 27 with doctorates and 35 with Master of Science degrees, with 36 from Tier 1 schools. ARL strives for diversity of intellectual thought in its new hires and actively recruits from a wide range of schools.

New Hires Degrees Awarded by:

Bowie State University

Broome Community College

CUNY Graduate School & University

Duke University

East Carolina University

Florida Institute of Technology

George Washington University

Harvard University

Indiana University

Johns Hopkins University

McNeese State University

Morgan State University

New Mexico Institute of Mining and Technology

New Mexico State University

New York University

Northwestern University

Oregon State University

Penn State University

Purdue University

Rollins College

Stanford University

Strayer University

Temple College

Texas A&M University

Towson University

University of California-Berkeley

University of Central Florida

University of Colorado

University of Connecticut

University of Delaware

University of Florida

University of Illinois

University of Kansas

University of Maine

University of Maryland - Baltimore County

University of Maryland - College Park

University of Mississippi

University of North Carolina at Chapel Hill

University of Pittsburgh

University of Tennessee

University of Texas at El Paso

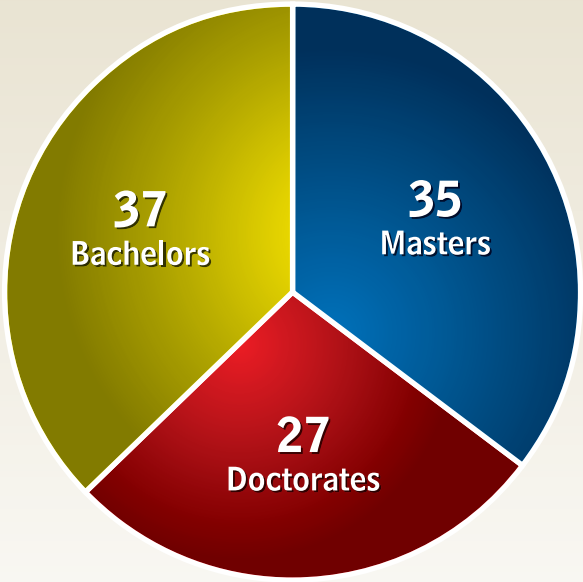
University of Wisconsin

Virginia State University

Webster University

West Virginia University

Yale University



Outreach Initiatives

At ARL, we understand that science and technology have been and will remain the engines of economic growth and national security in the United States. In addition, we understand that excellence in discovery and innovation in science and engineering are the direct result of a well educated workforce. It is a workforce that is being challenged by two trends: the global competition for science and engineering talent that impacts the pool of available scientists and engineers (S&Es) available in the United States; and the declining number of native-born S&E graduates entering the workforce. ARL is poised to intervene and improve the success in educating S&E students from all demographic groups, especially those that have been historically underrepresented in S&E careers.

With these national concerns and challenges in mind, ARL has made a corporate commitment to help develop the next generation of Army scientists and engineers by establishing an Outreach Program (OP) Office. The OP was expressly designed to address the projected shortfall of scientists and engineers among diverse populations of the 21st Century, to leverage technical capabilities of academia (including HBCU/MIs) to fulfill ARL requirements, and to expand the involvement of HBCU/MIs in ongoing research at ARL. The objective of ARL's OP Office is to develop and execute programs that provide learning and teaching aids, incentives, and rewards for students and teachers while ensuring opportunities for socially and economically disadvantaged students.

Key programs include:

ARL Summer Student Symposium

eCybermission (the Science Fair for the Nation)

FIRST – For Inspiration and Recognition of Science and Technology

GEMS – Gains in the Education of Mathematics and Science

JSHS – Junior Science and Humanities Symposium

MWM – Materials World Modules

REAP – Research and Engineering Apprentice Program

SEAP – Science and Engineering Apprentice Program

SMART – Science and Mathematics with Application of Relevant Technology

STARS – Science and Technology Academic Recognition System

UNITE – Uninitiates Introduction to Engineering

For more information, visit: www.arl.army.mil/outreach

Calandra Tate Moore – from STARS to USMA – Tate Exemplifies Strength of ARL Outreach

Dr. Calandra Tate Moore is well-suited for her role at the forefront of Army Research Laboratory (ARL) outreach efforts at the United States Military Academy (USMA) at West Point, N.Y. A 10-year employee at ARL, Tate received her entry to ARL through STARS, one of many outreach programs offered by the laboratory.

Tate, who is in her second year as ARL's visiting scientist at USMA, serves as a mathematician in the Multilingual Computing Branch in ARL's Computational and Information Sciences Directorate (CISD). The program allows ARL to send a scientist to USMA to teach classes in the mathematics department and serve as a liaison for ARL. She also helps Cadets identify research projects for summer tours at ARL, and brings in ARL scientists for seminars at USMA.

For Tate, it is also a valuable opportunity to give back to the organization that gave her a start in her field. Prior to her senior year at Xavier University in New Orleans, La., Tate was recruited to work at ARL for a summer through the STARS program. The relationship eventually brought Tate to ARL after her graduation, and enabled her to obtain a master's degree and a Ph.D. in applied mathematics at the University of Maryland.

"The outreach program has shaped my idea of research and helped me refine my goals," Tate said. "Being at ARL helped me solidify my research interests in language translation and exposed me to new fields and helped me develop my own research program."

After her time at USMA is over, Tate will return to ARL and continue her work in language translation. She also plans to stay involved in ARL outreach efforts, including summer programs and potentially hosting a Cadet from USMA.

ARL Outreach to USMA – A Valuable Partnership

As just one of its many valuable outreach efforts, the U.S. Army Research Laboratory has an ongoing partnership with the United States Military Academy at West Point, N.Y. Through this partnership, Cadets at USMA interact with Army scientists and help make significant contributions to the army community.

Lt. Col. Michael McCrea, coordinator of the Math and Science Center of Excellence and assistant professor at USMA, has firsthand knowledge of the direct benefit of ARL's outreach efforts at USMA, which help provide research opportunities, professional development and classroom instruction.

"It gives our Cadets the opportunity to see how science is applied on the battlefield," McCrea noted. "And it shows them that there are opportunities for them in the scientific field after they leave the military."

The program, which involves collaboration and exchange between the Cadets, faculty at USMA and ARL scientists, also provides a distinct benefit to ARL. "Our Cadets can give them insights and fresh ideas about things that Soldiers might need on the battlefield in the future," McCrea said.

As part of the arrangement, an ARL senior scientist holds a visiting chair at USMA for a period of one to two years to facilitate the relationship between ARL and USMA. Several USMA faculty members collaborate year round on research with scientists at ARL.

In addition, Cadets are given the opportunity to work at ARL facilities for a few weeks during the summer. This past summer, Cadets helped out in the areas of autonomous robots and precision-guided munitions, among other fields.

"Their experience shows them how the scientific community is working to improve their lives," McCrea emphasized.

Partnerships and Collaborations

Co-op Agreements, OTAs, TSAs, Contracts, Grants, CRADAs

ARL is partnering and collaborating with academia, industry, and other government organizations through a variety of continuing and new innovative programs. Our intent is to maximize the use of our limited research dollars by leveraging the resource investments of our partners using a variety of approaches ranging from single investigator grants with individual university faculty, to large centers with groups and consortia, to direct collaborations between university research personnel and ARL in-house scientists, engineers and analysts.

Biotechnology

UCSB, MIT & CalTech

Biologically-derived:

- Sensors
- Electronics
- Information Processing

Soldier Survivability

MIT & ISN

- Protection
- Performance Enhancement
- Injury Intervention and Cure

Electromechanics & Hypervelocity Physics

IAT

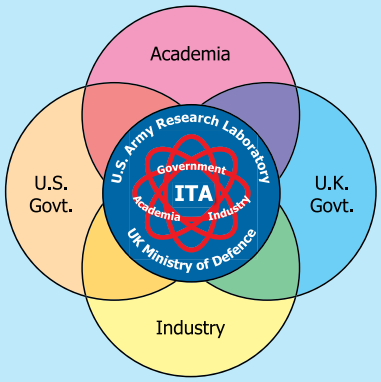
- EM Launch
- Pulsed Power
- Electric Armaments

University Affiliated Research Centers

Available Partnership Programs

Single Investigator Program
Multidisciplinary University Research Initiative Program
Collaborative Technology Alliances
Centers of Excellence
HBCU/MI ARO Core Grants
Battlefield Capability Enhancement Centers of Excellence
SBIR/STTR
University Affiliated Research Centers
Defense Experimental Program to Stimulate Competitive Research
Short Term Innovative Research

International Technology Alliance



Centers of Excellence

High Performance Computing
- Stanford University
- New Mexico State University
- Morgan State University
- University of Texas, El Paso
- High Performance Tech, Inc.
- NASA - Ames

Flexible Displays
- Arizona State University

Materials
- University of Delaware
- Johns Hopkins University
- Rutgers University
- Drexel University
- Virginia Tech

Battlefield Capability Enhancement Centers

Human Centric C2& Decision Making	Intelligent Sensor Fusion	Environmentally Stable Flexible Displays	Flexible Extremities Protection	Digital Battlefield Communication
North Carolina A&T State University	Tennessee State University	North Carolina A&T State University	Tuskegee University	Prairie View A&M University

Collaborative Technology Alliances

Advanced Sensors	Robotics	Power & Energy	Comms & Networks	Advanced Decision Architectures	Micro Autonomous Systems & Technology
					

Many Minds

Recognition and Awards

ARL Engineer Honored at Black Engineer of the Year Awards

Yolanda Hinton, a mechanical engineer in the Vehicle Technology Directorate (VTD), was honored for her efforts with a Special Recognition Award presented at the 22nd Black Engineer of the Year Awards Ceremony in Baltimore. The annual ceremony recognizes the achievements of African-American leaders. In addition to her technical accomplishments as an engineer since joining the federal government, Hinton has served as a kind of volunteer "ambassador" for young science and engineering students by encouraging and assisting them to pursue a technical education and career.

ARL Scientist Receives Prestigious Award from Society of Women Engineers

Dr. Melanie Cole, a research scientist in the Army Research Laboratory's Weapons and Materials Research Directorate (WMRD), was the recipient of the Society of Women Engineers (SWE) 2008 Achievement Award. The award is the highest honor given by SWE to an individual. Selection is based on the significance of the nominee's lifetime achievements and on her sustained contributions to the field of engineering. Among her many contributions to the ARL mission, Cole has helped establish ARL as the Army's technical lead in the area of active thin film materials technology in support of Future Combat Systems communication and radar platforms.

U.S. JAYCEES Recognize ARL Employee With "Ten Outstanding Young Americans" Award

Dr. Stephen Lee, chief scientist in the U.S. Army Research Office (ARO), was awarded the U.S. Junior Chamber (JAYCEES) Ten Outstanding Young Americans Award for 2008. The award exists to recognize and honor ten Americans each year who exemplify the best attributes of the Nation's young people, aged 18 through 40. As the senior scientist in the director's office of ARO, Lee has been working to develop new tools and capabilities to save lives of both civilians and Soldiers in Iraq and Afghanistan, as well as encouraging the growth of the U.S. Army's basic research program.

ARL Engineer Selected for AMC Award

Dr. Adrienne Raglin, an electronics engineer with the Computational and Information Sciences Directorate (CISD), was selected to receive the Louis Dellamonica Award for Outstanding Army Materiel Command (AMC) Personnel of the Year. The award recognizes outstanding work accomplishments that have significantly contributed to AMC's mission and overarching goals and objectives. Ten AMC employees are recognized annually. Raglin has been an engineer with ARL and the Army Institute for Research in Management Information, Communications, and Computer Science (AIRMICS) since 1989.

ARL Engineer is Finalist for Service to America Medal

Patricia Frounfelker, an engineer with the Survivability/Lethality Analysis Directorate (SLAD), was one of 29 federal government employees selected as a finalist for a Service to America Medal by the Partnership for Public Service. She was selected for her work in discovering hazards associated with reactive armor that prompted safety improvements for Soldiers and Marines.

2008 Research and Development Achievement Awards

Sensors and Electron Devices Directorate:
- Lam Nguyen
- Brian Stanton
- Francois Koenig
- David Wong
- Dr. Larry Merkle
- Dr. Kwong-Kit Choi
- Dr. Rongzhong Jiang
- Marc Ressler
- Gregory Smith
- Karl Kappra
- Dr. Mark Dubinskiy
- Dr. George Newburgh
- Dr. Deryn Chu

Weapons and Materials Research Directorate:
- Arron Bard
- Thomas Harkins
- Dr. Ernest Chin
- Dr. Margaret Hurley
- Peter Bartkowski
- Bradford Davis
- Dr. Edward Byrd
- Dr. Betsy Rice

Vehicle Technology Directorate:
- Gary Skoch

2008 Wilber Payne (Large Group) Award for Best Army Analysis

- Mark Mahaffey – SLAD

Department of the Army Lean Six Sigma Certifications (Green Belt)

- Maria Hovatter – HRED
- Messina Enderlein - WMRD
- Dr. Sandra Young - WMRD
- Fred Thompson - Laboratory Operations
- Darlene Sturgill - Laboratory Operations
- Shelia Boyd - Laboratory Operations

2008 Army Information Assurance Director's Award for Leaders of Influence

- Daniel Landin- SLAD

2008 MANPRINT Practitioner of the Year Award

- Thomas Haduch – HRED
- Jim Faughn – HRED
- Lt. Col. Kathy Moses – HRED
- Richard Kozycki – HRED
- Ron Carty – HRED

Hispanic Engineer National Achievement Awards Conference – Luminary Honoree

- Manuel Bustillos, Sr. - CISD

Silver Snoopy Award – NASA Office of Space Flight

- Dr. Robert Handschuh – VTD
- Dr. Timothy Krantz – VTD

National Society of Black Engineers Alumni Member of the Year

- Dr. Barbara Nichols – SEDD

National Defense Industrial Association – Walter W. Hollis Award for Lifetime Achievement

- Dr. Paul Dietz – HRED

Army Materiel Command Engineer of the Year

- Mark Mahaffey – SLAD

2008 Baltimore Federal Executive Board – Excellence in Federal Career Awards

Gold:
- Tarasa Miller – WMRD
- Eric Klier – WMRD

Silver:
- Victor Champagne – WMRD
- Rex Hall – WMRD
- Heather Haywood and Rebecca Setters (Group Award) – SLAD
- Lawrence Burton – WMRD
- Dr. Ronald Weiss – SLAD

Bronze:
- Dr. Mark VanLandingham – WMRD

Army Modeling and Simulation Award

- Dr. Jessie Chen – HRED

2008 FCT Program Manager of the Year (OSD)

- Brian Placzankis – WMRD

Defense Manufacturing Excellence Award

- Victor Champagne – WMRD

2008 Research and Development Laboratory of the Year Awards - Collaboration Team of the Year

- HMMWV Improvement Project
- Joint Trauma and Prevention of Injury in Combat
- Mine Resistant Ambush Protected Expedient Armor Program
- Learning with Adaptive Simulation and Training/BiLAT

Recognition and Awards

Legion of Merit

Lt. Col. Brian Gollsneider

Bronze Star Medal

Lt. Col. Brian Gollsneider

Sgt. Maj. Steven Hornbach

Meritorious Service Medal

Maj. Christopher Ford

Maj. Brian Hackenberg

Maj. Paul Panozzo

Maj. David Tompkins

Sgt. 1st Class Deryck James

Sgt. 1st Class Craig Parker

Sgt. 1st Class Veronica Moore

Sgt. Jacob Warford

Army Commendation Medal

Master Sgt. Ralph Brewer

Sgt. 1st Class Jamesaam Taylor

Staff Sgt. Jerson Freire

Staff Sgt. Crystal Knott

Sgt. Richard Candelario

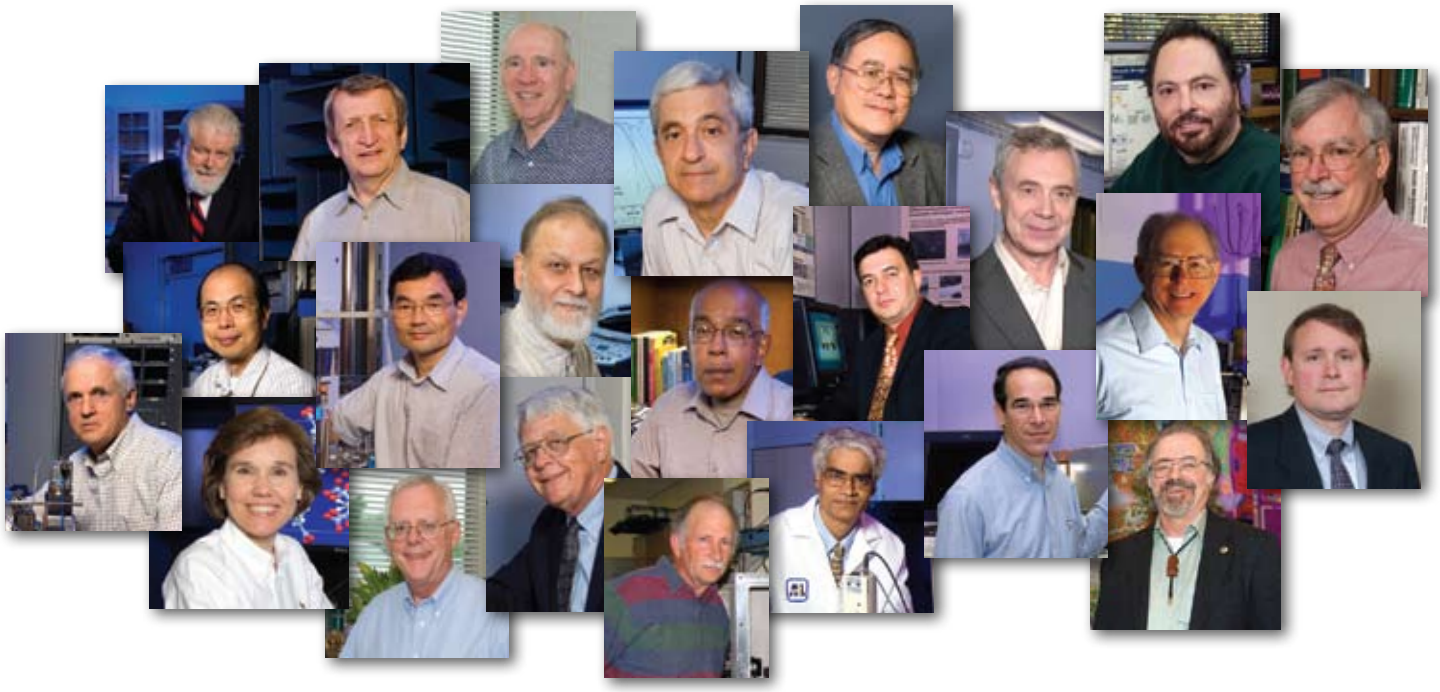
Army Achievement Medal

Staff Sgt. Collin Moore

Staff Sgt. Richard Adams

Many Minds

ARL Fellows



The Role of ARL Fellows

The Fellows of the Army Research Laboratory play a vital role at the laboratory. Their overall mission is to achieve, promote and maintain technical excellence in science and engineering at ARL. "Being an ARL Fellow is a great honor," says ARL Fellow Dr. Anathram Swami. "But concomitant with this honor are also great responsibilities." These responsibilities can include any function or service that might assist ARL in the aforementioned mission. The Fellows serve as advisors and consultants on technical matters to the ARL Director and the Directorate Directors.

Among some of their more important contributions have been evaluations of ARL technical awards, organizing special symposia, and chairing directorate promotion panels. In addition, each year the Fellows review proposals for the Director's Research Initiative, which is designed to support innovative and possibly high-risk research ideas that have the potential to significantly advance mission needs beyond conventional expectations. The Fellows have also recently launched the ARL Fellows Colloquium, a valuable opportunity for interesting research and topical discussions relevant to ARL and the Army.

ARL Fellows: An Elite Group

The Fellows of the Army Research Laboratory are carefully chosen from the ARL community, itself a distinguished collection of some of the top scientific minds in our Nation. ARL Fellow Dr. Peter Reynolds notes that election as a Fellow is based on "exceptional technical accomplishment, reputation, technical leadership, impact, and the prospect of continued productivity." Only two percent of the scientist and engineer workforce at ARL can be Fellows. The selection criteria include an emphasis on those doing the very highest quality ongoing S&E work, combined with extremely high impact on Army, the mission, and their field of endeavor.

The first ARL Fellows were elected in 1993. The Fellows endeavor to be representative of ARL as a whole. To this end, the ARL Fellows Charter provides procedures that assure a field of candidates drawn from the entire laboratory. There are currently 23 Fellows, 26 Fellows emeriti, and two Honorary Fellows.

Summer Student Symposium

This year's program consisted of 110 undergraduate and graduate students who participated as interns in ARL research programs. All students wrote a paper describing their work and the results of their research. The papers were reviewed by each directorate, and the top undergraduate and graduate students were selected to deliver their presentations to the ARL workforce at the ARL Summer Student Symposium on Aug. 7, 2008. The research papers highlighted educational and scientific aspects of the students' ARL experience and demonstrated the progress made during the summer. Eleven students were selected to present their papers during the symposium. A panel of nine ARL Fellows judged the papers and presentations to select the winners. They also selected one "best paper" award from among students unavailable to give presentations because their internships ended prior to the symposium.

Graduate Winner: Claire Weiss, University of Connecticut, for "Novel Thin Film Materials for Tunable Device Applications."

Undergraduate Winner: John Bender, The University of Maryland, Baltimore County, for "Development of Miniaturized Photoacoustic Chemical Sensor."

Director's Research Initiative

The Director's Research Initiative (DRI) is designed to support innovative and possibly high-risk research ideas that have the potential to significantly advance mission needs beyond conventional expectations. The program encourages thinking "outside the box" in pursuing emerging or alternative technologies for which direct application to today's problems might not be possible, but which could have potential to address military needs in the long term.
DRI proposals are ranked according to degree of innovation and risk, while weighted by soundness of scientific approach. Proposals can be either for basic or applied research. Among the requirements are that the proposal is scientifically and technically innovative in concept and approach; new or sufficiently novel work; consistent with the ARL mission; and exclusively or primarily in-house.

ARL scientists and engineers are encouraged to submit proposals that address an Army problem, objectives, barriers, cost for one year, bibliography, and investigator qualifications. Successful proposals are eligible to be renewed for a second year.

The DRI review process is conducted by the ARL Fellows. The proposals are independently evaluated by at least four panel members most knowledgeable in the field that the proposal was written. They are then scored with respect to originality of scientific approach, soundness of scientific methodology, importance to the scientific field or technology, importance to the Army in terms of improved materiel or operational capability, and potential value to the ARL mission program. The resultant rankings are provided to the ARL Director, and his selections are made accordingly.

Infrastructure

To maintain our state-of-the-art status in facilities, ARL funds numerous infrastructure and equipment projects. In FY08 ARL invested over $25 million in new equipment and upgraded facilities. Highlighted here are three just completed or scheduled projects. ARL's Environment for Auditory Research (EAR) was completed in FY07 and became fully functional in FY08. This world-class facility is already providing researchers with a powerful tool unmatched throughout the world. Additionally, the Electromagnetic Vulnerability Assessment Facility (EMVAF), completed in FY07, is quickly becoming one of the Army's premier and unique facilities providing controlled electromagnetic measurements. And finally, a milestone was reached with the completion of architectural drawings for the new Vehicle Technology Directorate's facility that will be built at Aberdeen Proving Ground, Md., as a result of the 2005 Base Realignment and Closure.

Up until this past year, the scope of our projects was limited by the minor construction dollar threshold of $750,000. The Defense Authorization Act for FY08 raised that threshold to $2 million for Defense Laboratories. Using this new authority, the Director, ARL, approved three new infrastructure projects that would not otherwise have been possible. These are: a new preparation/antechamber for the EMVAF at White Sands Missile Range, N.M., the Autonomous Systems Technology facility and the Solider Performance and Equipment Advanced Research (SPEAR) at Aberdeen Proving Ground. All three are much needed improvements to ARL's facilities.

The EMVAF prep room enhances the capabilities of this facility. It provides a weather shield to the interior of the large anechoic chamber, interior space, with all required functionality such as power so that large systems (e.g. tanks, helicopters, C2 nodes) can be prepared prior to experimentation in the large chamber. This avoids downtime for the large test chamber and increases the number of tests that can be performed. The prep room has the added benefit of reducing maintenance costs for the large chamber.

Autonomous Systems Technology facility: The facility will house 1) a Small Robotics Laboratory that includes experimental set-ups and mobility-challenge scenarios to emulate certain urban combat situations, 2) a Microsystem Aerolab that includes a small wind-tunnel and water channel to conduct low-Reynolds-number aeromechanics research, 3) a Drives and Control Laboratory to support research in robotic manipulation, ambulation, and advanced mobility, and 4) a Rolling Testbed Laboratory that supports small UAV, active rotor, and air-ground teaming experiments.

Soldier Performance and Equipment Advanced Research: The new facility will provide researchers with the capability to conduct separate and networked studies of individual and team performance in a tactical, controlled operational environment. This includes: adding an advanced immersive psychological environment to evaluate Soldiers in more realistic battlefield scenarios, with the added value of monitoring and tracking participants while they engage in combat-related and/or simulated tasks. The improvements will also allow more controlled study of individual and team performance under varying task demands, as well as provide a means to control stimuli during scenarios, such as targets and auditory sounds and cues, all to be controlled by a central computer system. Also, as part of the Technology Program Annex between the Aberdeen Test Center (ATC) and the ARL-HRED, the new facility will be electronically networked with the Military Operations in Urban Terrain (MOUT) facility at Mulberry Point, Aberdeen Proving Ground, Md. By combining the ATC MOUT capabilities with HRED's Soldier performance expertise, the new facility will provide the ability to study Soldier cognitive, perceptual and physical/physiological performance in real-time dynamic MOUT and selected combat environments.

An ARL researcher prepares to conduct auditory research in ARL's state-of-the-art Environment for Auditory Research facility that was dedicated in 2007 and became fully operational in 2008.

Environment for Auditory Research (EAR)

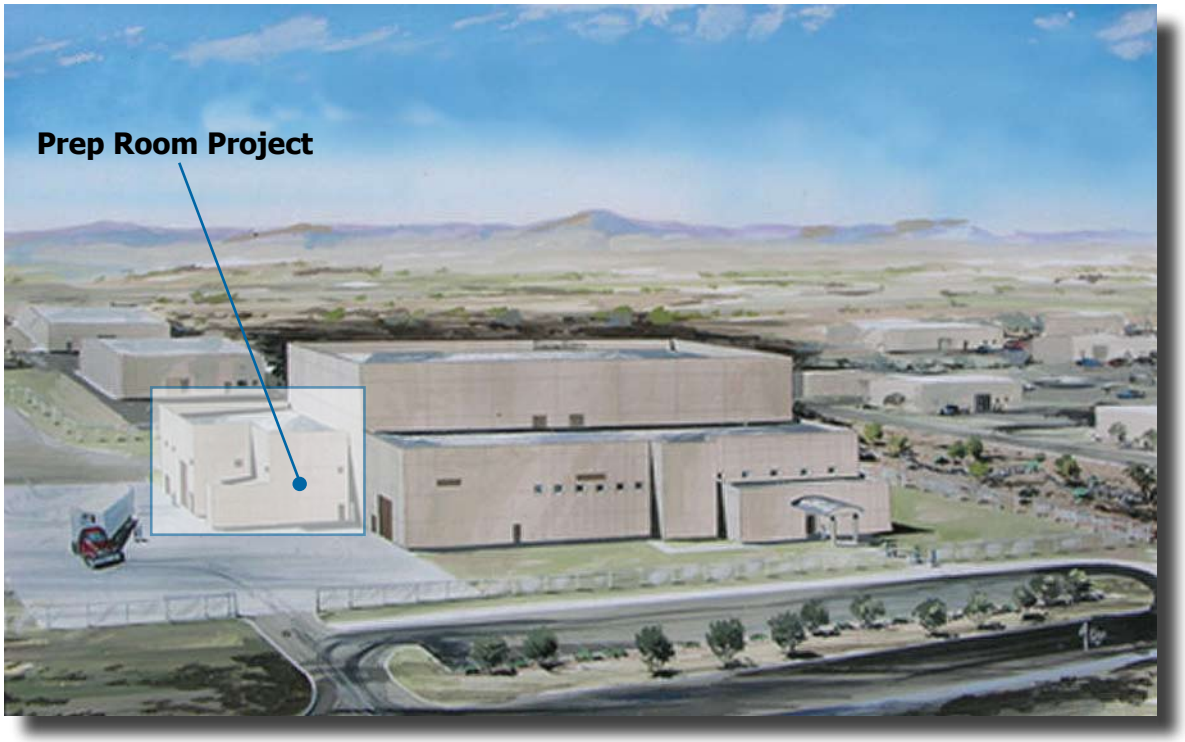
The Environment for Auditory Research (EAR) is an auditory perception and communication research center permitting state-of-the-art simulation of various indoor and outdoor acoustic environments. The EAR was designed from the ground up for auditory research to address deficiencies of existing ARL research facilities. The heart of the EAR is the Control Room — an integrated control center permitting complete control of instrumentation and research activities in all five listening spaces. The Sphere Room is an auditory virtual reality space designed to investigate the integrity of auditory virtual spaces and realism of complex auditory simulations. The Dome Room is designed to study the human's ability to localize real or virtual, single or multiple, and stationary or moving sources distributed in a hemispherical space. The Distance Hall is designed to permit extensive investigation of auditory distance perception and localization and tracking of sound sources moving in a predetermined manner toward and away from the listener. The new ARL Environment for Auditory Research is a unique and powerful research tool, and in combination with the capabilities of the OpenEAR creates a research complex unmatched at any military, academic, or industrial facility world-wide.

Infrastructure

Electromagnetic Vulnerability Assessment Facility (EMVAF)

The Electromagnetic Vulnerability Assessment Facility (EMVAF) was conceived to afford the Army with the capability to conduct controlled electromagnetic measurements supporting Test and Evaluation and Science and Technology tests as well as experimentation and analysis events. In addition, ARL's primary mission of vulnerability assessment in the areas of electronic warfare, radio frequency directed energy, computer network operations, and counter-IED was expected to be addressed by the EMVAF facility. The facility is electromagnetically shielded providing over 100 dB isolation for its two anechoic chambers. The large chamber is designed with multiple access doors to include a door which is larger than the cargo doors on a C5A Galaxy transport aircraft. In combining all of the special features of this facility, the EMVAF is one of the Army's premier and unique facilities.

Up-armored HMMWVs are about to undergo electromagnetic measurements at ARL's new EMVAF facility at White Sands Missile Range, N.M.



The new Prep Room at ARL's EMVAF facility will minimize downtime, increase efficiency and reduce costs.

Vehicle Technology Directorate

A significant milestone was reached during FY08 with the completion of the 30-percent design drawings for the new Vehicle Technology Directorate at Aberdeen Proving Ground, Md., resulting from the Base Realignment and Closure. A range of facility options were identified. An assessment of these options led to recommending that the Army invest $35 million for research facilities at APG and agree to the establishment of VTD field elements (11 employees) at NASA sites. This option provides baseline laboratory facilities at APG for execution of critical technologies within the VTD mission set and places affordable field elements at NASA sites to take advantage of key facilities that are too expensive to build at APG — truly the best compromise between new and existing facilities. Via multiple presentations, meetings, and information papers, ARL articulated the importance of VTD's mission to the Army's leadership and was successful in obtaining approval and resources for facilities at APG.

New Home: ARL's Vehicle Technology Directorate will move to Aberdeen Proving Ground, Md., as a result of the 2005 Base Realignment and Closure.

Program Formulation

In April 2008, the ARL-wide Program Formulation Workshop was conducted with our customers and stakeholders to help define ARL's FY09 research mission priorities. By centralizing the process, we created a forum to communicate to and receive programmatic input and feedback from our stakeholders (i.e., Research, Development and Engineering Centers, Program Engineering Officers, Program Managers, Life Cycle Management Command, U.S. Army Training and Doctrine Command, Office of the Deputy Chief of Staff, G-1, G-2, G-4, Special Operations Command, Intelligence and Security Command, Space and Missile Defense Command, Medical Research and Materiel Command, and Other Government Agencies) on our proposed FY09 mission program.

Much of ARL's research program is executed in collaboration with external research partners. Building on the success of our first laboratory-wide program formulation workshop for our FY08 program and in response to our stakeholders' interest in seeing the entire spectrum of our research, we expanded the scope of the FY09 workshop to include our Collaborative Technology Alliances, Centers of Excellence, and University Affiliated Research Centers.

Our goal for this annual workshop was to receive input on our proposed FY09 mission program and then make the necessary adjustments to best serve the Army's needs. This consolidated workshop not only enabled our stakeholders to receive a comprehensive presentation of ARL's proposed program plan but provided a single forum for stakeholder interaction to influence, prioritize, and mature our program plan.

This three-day workshop was attended by many of our customers and stakeholders, including HQ RDECOM, the RDECOM RDECs, OASA (ALT); HQDA; HQ AMC; G-2; G-4; G-6; DTC; DARPA; MDA; AARL; ATEC; AEC; ARI; HPCRC; INSCOM; JIEDDO; MRMC; RDECOM; SMDC; SOCOM; TRADOC; JPEO CBD; PEO AMMO; PEO AVN; PEO CS&CSS; PEO IEWS; PEO Soldier; PM Joint Services; PM/NV RSTA; USMA; AFRL; all Battlefield Capability Enhancement activities; DOE (ANL, ORNL); FDC; CTA/ADC; CTA/Robotics; CTA/Comms and Networks; ICT; ISN; ICB; JPL; MAST; NIST; NRC; NRL; ONR; ONAMI; NRC TAB. The active participation of and interaction with our stakeholders provided them the opportunity to submit substantial suggestions and comments.

ARL tracked and addressed each of the stakeholders' comments and modified our FY09 mission program and Annual Performance Plan accordingly. As a result, we have a research program that more closely meets our stakeholder's needs with improved understanding of deliverables and more meaningful milestones.

An Interactive Workshop

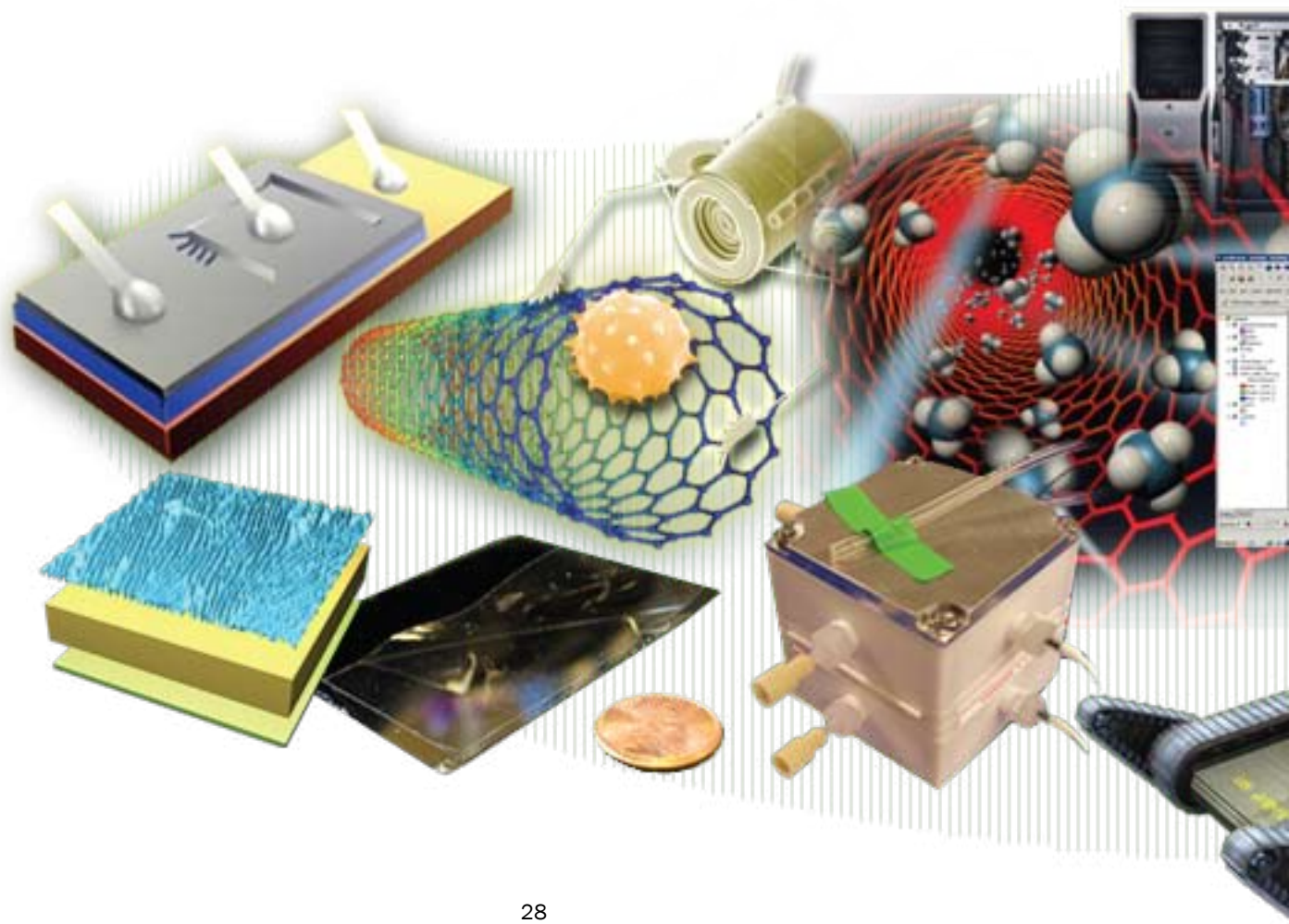
ARL's customers and stakeholders were afforded numerous opportunities throughout the Program Formulation Workshop to interact with ARL subject-matter experts and technology resulting in more meaningful dialogue.

Strategic Technology Initiatives

The U.S. Army has transformed into a high-technology organization, relying on cutting edge research and analysis to maintain its dominance. Many of ARL's current programs exist as a result of strategic investments initiated a decade ago. As we look toward the future for the Army, we continually engage in strategic planning for major segments of our technical mission. Our knowledge of Soldier's future needs and gaps in material capabilities allows us to critically analyze our programs and identify new areas.

To fill critical Army voids, we have selected seven high-payoff areas emerging from state-of-the-art science and engineering. Each strategic technology area has the long term potential to deliver unprecedented capabilities for the Soldier. Three are furthering basic science for military applications—neuroscience, biosciences, and network science. Three are focused on developing new technologies for Soldiers and systems—autonomous systems technology, power and energy, and advanced computing. And, lastly, one is developing new analysis capabilities to improve and evaluate Soldier decision making for military networks—system of systems analysis.

Strategic technology initiatives (STIs) in these areas support the laboratory's tradition of providing cutting edge research for our next generation of Warfighters. STIs are high risk with the potential for producing radical, game-changing advancements in analysis, technology or warfighting capabilities. These initiatives are inherently long term and cross disciplinary in nature. Each may require extensive efforts before delivering innovative capabilities. ARL scientists and engineers are encouraged to pursue their creative ideas through this program. Success will help ensure decisive warfighting superiority for our Soldiers and enhance the foundation our world-class laboratory.



Science STI:

Biosciences
Neuroscience
Network Science

Technology STI:

Advanced Computing
Autonomous Systems Technology
Power and Energy

Analysis STI:

System of Systems Analysis

Many Capabilities

Support to Current Operations

ARL takes a very active role in working with our RDECOM and Army partners to provide technical expertise and assistance in support of ongoing operations. ARL mission investments over time are bearing fruit as technologies are spun off for applications to Current Force capability gaps and requirements. The full spectrum of ARL support provided includes developing technology solutions to solve current-force issues, technical field assistance for fielded equipment, training troops in use of the fielded prototypes, and analytical support.

In FY08, our support to current-force operations ranged from work on reducing the weight of armor for MRAPs to providing persistent surveillance capabilities to supplying counter IED systems to Operation Iraqi Freedom. A brief description of some of these efforts follows.

MRAP Armor

Forecasting the need for better and lighter protection from Improvised Explosive Devices (IEDs), ARL developed aggressive weight reduction goals and set out to demonstrate practical technology options by the end of FY08.

Maxx Pro vehicles awaiting deployment to theater (Operation Iraqi Freedom - OIF).

A partnership was formed between RDECOM and the MRAP Joint Program Office (JPO) that resulted in RDECOM accelerating the development of IED protective technology and JPO redirecting its set of original equipment manufactures to add vehicle payload capacity.

The overall requirement was that the introduction of armor production could not delay the highly aggressive deployment schedule of MRAP equipment to theater.

The program's combined technical approach was to exploit high-performance computing and highly instrumented terminal effects experimentation in order to scale known technologies for the defeat of IED threats, understand the most viable armor mechanisms for efficient penetrator defeat, and then introduce light-weight composites, new materials and enhanced ballistic mechanisms in order to reduce the add-on weight of final armor packages.

The technical challenge to RDECOM was that technology originally envisioned as high-risk for a one year developmental program, was now required to be production-ready within five months; this program was led by ARL and became known as the MRAP Armor Weight Reduction Spiral (MAWRS) Program.

The challenges were overcome by the assembly of talent from across ARL and the Aberdeen Test Center, and the armor designs were incorporated and produced on vehicles delivered to theater.

Col. Bobby Smith

Col. Bobby Smith serves as the military deputy to the ARL director and provides the Soldiers' perspective for current and future technologies. Although he's been in the position since August 2007, he spent six months of the time serving as the senior Science, Technology and Acquisition Corps Advisor (STACA) for the Multi-National Corps – Iraq.

While in the role, Smith said he saw firsthand the great things ARL is doing for the troops in theater. "We provided the Warfighter the technology that minimized the (improvised explosive device) IED threat," said Smith. "What we do here directly impacts the Soldier in terms of life and death."

Smith adds the six-month tour in Iraq to his extensive acquisition management experience and is now tackling the unique challenge of understanding the research side of the process. "The biggest challenge is to fully understand the link between basic and applied research," he said "and the process the technology follows—from the laboratory to the project managers—to the acquisition community."

He said his input to ARL is important, but it's the Soldiers who are actually using the new technologies he wants to hear from. "When a Soldier tells you what you did for them makes a difference, that's what speaks volumes about the entire organization," said Smith.

Sgt. Maj. Steve Hornbach

Acting as the senior enlisted advisor to the ARL Director for the last two years, Sgt. Maj. Steve Hornbach is a combat engineer who brings 29 years of military experience to ARL. "I'm taking care of all of the Soldiers' needs and the needs of the leadership," said Hornbach. "I give them guidance on Soldier issues."

Although ARL doesn't have many servicemembers, Hornbach said the 40 to 60 noncommissioned and commissioned officers here perform an extremely important and unique mission by acting as Soldier-to-scientist communicators. "You have to have that interface," said Hornbach. "A scientist doesn't talk like a Soldier."

ARL Soldiers also deploy to the combat zone as members of Field Assistance in Science and Technology teams to help prioritize technology requirements for the Warfighters, and Hornbach returned from nearly six months on the team in February. "Biggest thing is—if there's a problem, they go out and try to find a solution," said Hornbach. "We want the advantage on the battlefield."

Helping to fulfill the Warfighters' technological needs was the priority for Hornbach's team, and he said he believes everyone at ARL is also extremely focused on the mission. "We all know who we work for—everyone works for the Soldiers," said Hornbach. "If we can develop a piece of technology here that saves one Soldier's life, we've done our job."

Support to Current Operations

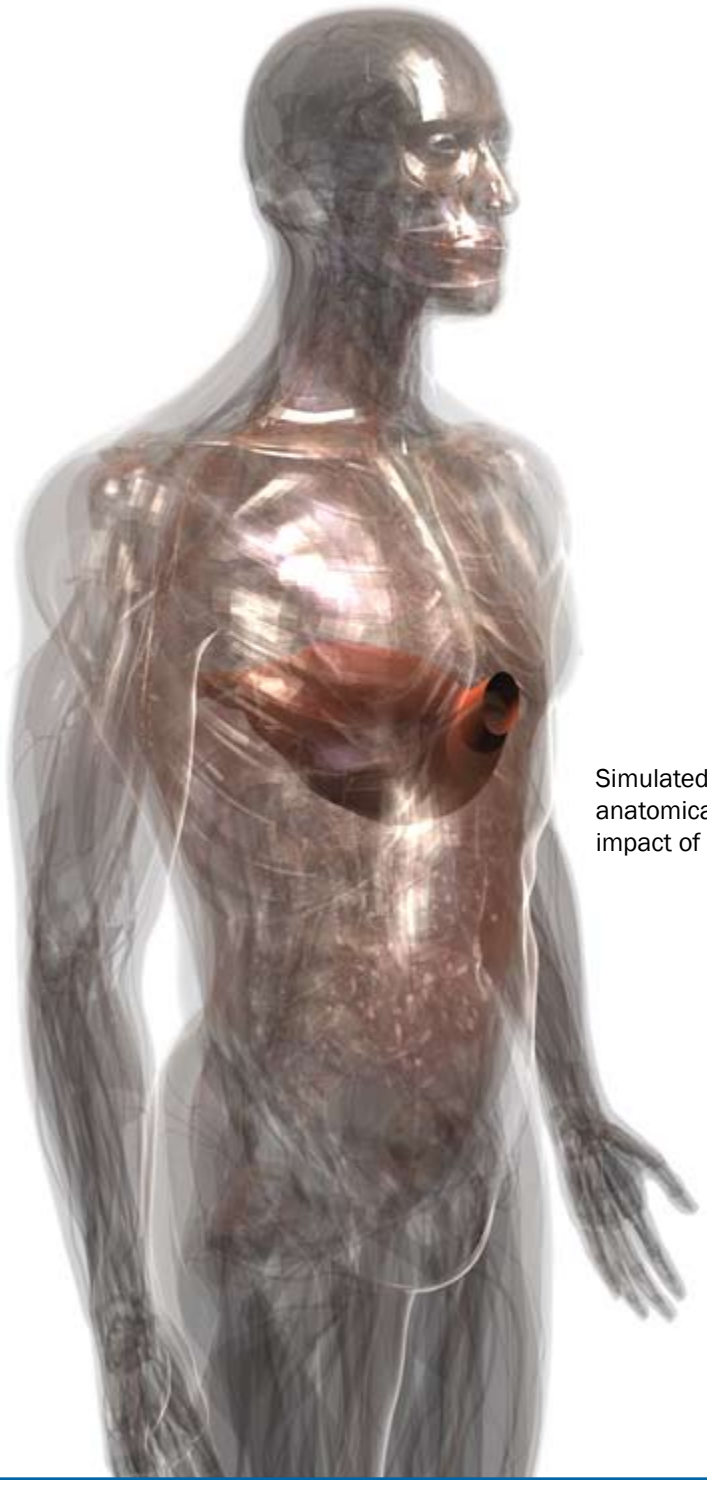
Joint Trauma Analysis and Prevention of Injury in Combat

ARL leads the modeling and survivability analysis effort in a joint program in which battlefield events that led to casualties are reconstructed to identify lessons that may be learned for improved materiel, tactics, or intelligence value.

Specifically, ARL is characterizing fragments, has constructed and is populating a fragment database, and is analyzing and modeling selected fragments and resulting wounds.

The Joint Trauma Analysis and Prevention of Injury in Combat (JTAPIC) program is a collaborative effort with partners from the medical, intelligence, academic, materiel developers, and service laboratories aimed at leveraging each organization's capabilities to "reverse engineer" the crime scene.

Recent efforts have demonstrated success in identifying threat munitions, likely battlefield scenario, and highly detailed analysis on potential improvements to survivability equipment resulting from specific cases from IED and direct fire, close combat, and thoroughly studying weapons-induced fragments retrieved from surgeries and/or autopsies, which may have caused lethal or serious injuries to service members.



Simulated wound pattern in a anatomical geometry resulting from the impact of a kinetic energy projectile.

Language Translation Capabilities

The Army Research Laboratory Language Translation Program has spent considerable time in developing, fielding, evaluating, and improving language translation capabilities in the current theater of operations.

Utilizing the deployment of ARL Soldiers on the Army Materiel Command Field Assistance in Science and Technology (FAST) Teams in both Iraq and Afghanistan, the language center has been able to deploy the Phaselator P2 devices, established call back channels to provide feedback from the users, and identified shortcomings in the systems that have been addressed.

One such report from Iraq (Corps of Engineers, Gulf Region South District) has been forwarded through command channels, along with a request for information (AMC-FAST RFI) on numbers and locations of deployed systems. As each successive FAST Team deployed, they were able to build upon the knowledge and experience and to extend the training, trial and feedback sequence exposing Military Police units to late-model Phraselator devices running new two-way speech translation software produced by IBM.

While feedback on surveys indicates that the devices compare unfavorably to human interpreters, valuable insights are being amassed on appropriate use cases, concept of operations (CONOPS) and tactics, techniques and procedures (TTPs) for speech translation devices in current and future military operations. The current FAST Team is currently ensuring that Phraselator devices in both one-way and two-way configurations are getting into the hands of OIF Soldiers who are likely to use the technology to military advantage.

Master Sgt. Ralph Brewer

With more than 20 years of military experience, Master Sgt. Ralph Brewer is a combat veteran who fills a unique position working in ARL's Robotics Program Office. Brewer's primary responsibility is to give a Soldier's input to the researcher, which he said makes it more relevant to the Warfighter.

"We want them (Warfighters) to be the most technologically advanced force in the world, and it starts at ARL," he said. "It's important to have Soldiers involved in the process ... to give that military perspective to the engineers and scientists."

Along with his technical job, the armor Soldier also enjoys participating in ARL's comprehensive educational outreach program. He works with children starting at middle-school aged to inspire them to study the math and science needed to eventually become researchers at ARL.

"Our future is going to be with those kids," said Brewer. "But, it just doesn't happen overnight." Although working at ARL exposed Brewer to a part of the Army he never knew existed before, he said he still feels like he's part of the bigger mission.

"Working here is great because I really got to know and understand how ARL fits into the Army Materiel Command and the whole Army," said Brewer. "The other thing is knowing the input I have in the technology can save lives."

Dr. David Skatrud
Director ARO
Deputy Director - Basic Science
Extramural Basic Research

Dr. John Pellegrino
Director for Sensors
& Electron Devices
Sensing and Power & Energy

Jill Smith
Director for Weapons
& Materials Research
Lethality and Survivability

Dr. John Gowens
Director for Computational
& Information Sciences
Networks

Dr. Paul Tanenbaum
Director for Survivability
/ Lethality Analysis
Survivability / Lethality Analysis

Dr. Paul Deitz (A)
Director for Human Research
& Engineering
Human Dimension

Dr. Mark Nixon
Director for Vehicle Technology
Mobility

Dr. David Mann
Director for Physical Sciences
Extramural Basic Research

Dr. Tom Doligalski (A)
Director for Engineering Sciences
Extramural Basic Research

Dr. Randy Zachery (A)
Director for Mathematical
& Information Sciences
Extramural Basic Research

The remainder of this review is structured around our nine major laboratory programs of Extramural Basic Research, Networks, Human Dimension, Lethality, Mobility, Power and Energy, Sensing, Survivability, and Survivability/Lethality Analysis.

The accomplishments presented here, while only a small sample of our efforts over the past year, are representative of the skill, dedication, and teamwork of our in-house staff and our partners in academia and industry.

Extramural Basic Research

- Novel Polycarbonates for Transparent Armor Applications
- Helicopter Performance and Acoustic Emission Prediction and Control
- Quantum Imaging/Ghost Imaging

Networks

- Mobile Ad Hoc Network (MANET)
- Battlespace Terrain Reasoning Awareness
- Intelligent Optics

Human Dimension

- Human Factors Analysis of Mine Resistant Ambush Protected (MRAP) Vehicle Seating and Restraint Systems
- Enhanced Joint Tactical Communications on the Battlefield
- Effectiveness of Concurrent Performance of Gunnery and Robotics Tasks and Effects of Cueing in a Simulated Mounted Environment

Lethality

- Technology Suite for Affordable Precision Munitions
- Nonlinear Unsteady Aerodynamics for Affordable Precision Projectiles
- Metastable Polymeric Nitrogen: A Disruptive, High-Energy, Green Energetic Material

Mobility

- Autonomous Aerial System Technologies
- Condition-Based Maintenance for Apache Aircraft Bearings
- Near Autonomous Operation of Unmanned Systems

Power and Energy

- Power MEMS
- Battery-to-Bus Converter for FCS

Sensing

- Piezoelectric Nanoswitch
- Flexible Reflective Displays
- Thick Polymer Films for Electro-Optic Laser Protection Shutter
- Family of UGS (Unattended Ground Sensors)

Survivability

- Multi-Service Ballistic Canopy for Military Rotorcraft Protection
- Transparent SPINEL Armor and Manufacturing Scale-Up
- Cold Spray Repair on Mechanical Damage to AH-64 Helicopter Parts

Survivability/Lethality Analysis

- Mine Resistant Ambush Protected (MRAP) Vehicle
- Future Combat Systems (FCS) System of Systems Common Operating Environment (SOSCOE) Version 1.8.X

Novel Polycarbonates for Transparent Armor Applications

Many different types of polymeric materials are used to make material that provides protection to Soldiers. They must possess certain properties, such as hardness and toughness, and have good resistance to chemicals, including oil and gasoline. One such material, polycarbonate (known commercially as Lexan®), has one additional useful feature – transparency.

As a result of this combination of toughness and transparency, polycarbonate finds uses in many applications, including helmet visors and goggles, automotive headlight covers, windshields and windscreens, hockey rink glass, and riot shields and helmets. The Army, DoD and security personnel currently use polycarbonate in armor applications where transparency is critical. Even though polycarbonate performs well, thermal stability precludes using this material in applications that experience elevated temperatures.

In an ARL funded project, professors at the South Dakota School of Mines and Technology are attempting to improve polycarbonate performance through fundamental research aimed at understanding the molecular level parameters that govern toughness. The practical goal is to improve overall performance and more specifically high temperature properties. For decades industry has worked on improving polycarbonate toughness with little success; this research is expected to lead to new approaches to polycarbonate materials with enhanced performance.

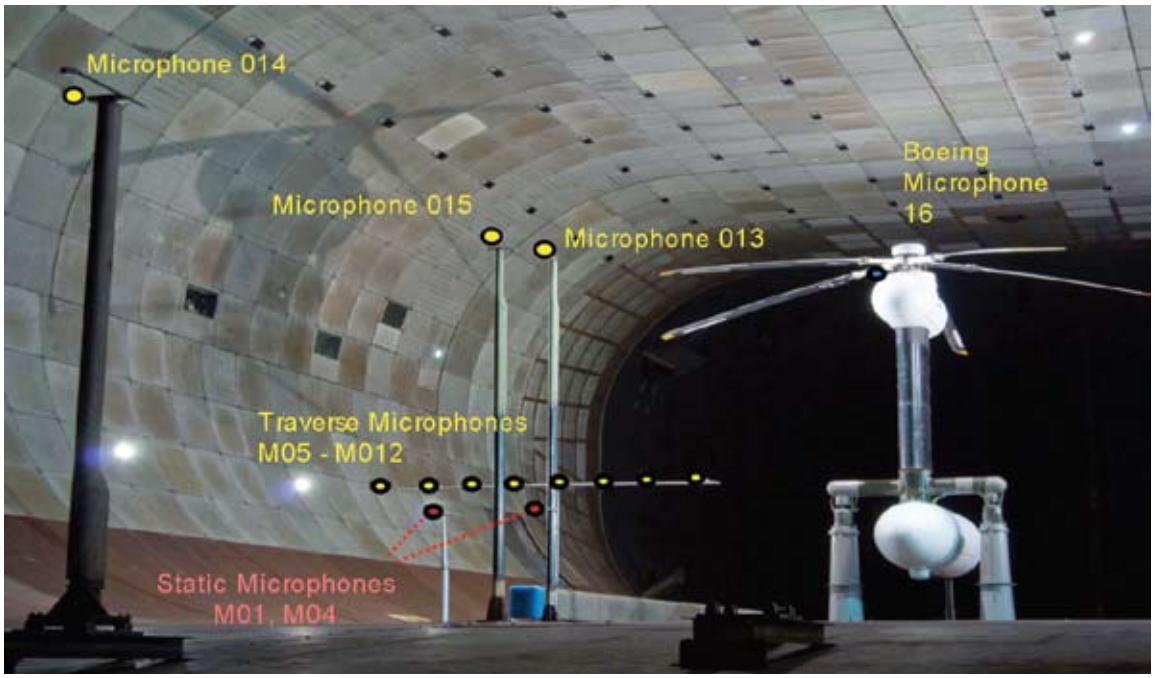
The researchers used molecular modeling to guide monomer and polymer synthetic efforts. They focused on an important fact, which is that assemblies of high aspect ratio monomer repeat units result in shorter packing lengths (i.e., the distance between molecules in a well-ordered arrangement of polymer chains). This parameter is important in determining polymer chain entanglement molecular weight, which helps control brittleness and can thus lead to tougher materials. A researcher's calculations suggested that materials with improved toughness would result from incorporating long, thin molecules of high-aspect ratio into the polymer chains. In order to test the hypothesis, another researcher designed and developed new synthetic schemes to prepare materials with these molecular characteristics.

ARL continued work in FY08 on transparent armor applications. Material such as polycarbonate provides the transparency and toughness necessary for use in helmet visors, goggles, automotive headlight covers, windshields and much more.

Using synthetic methodology that is directly amenable to industrial scale reactions, he synthesized more than 30 novel monomers and more than 100 new polycarbonate polymers and fully characterized these systems. One material, a tetrarylbisphenol-A derived polycarbonate, displays properties similar to commercial polycarbonate but possesses a higher glass transition temperature. This enhancement may allow the new material to be used in higher temperature applications where commercial polycarbonates fail.

In addition, it has shown promise during ballistic testing carried out by the Army. General Electric Corporation, a major polycarbonate producer, is collaborating with researchers to convert 10 pounds of monomer produced in the laboratories into polycarbonate polymers for further evaluation and testing.

Helicopter Performance and Acoustic Emission Prediction and Control



The NASA Ames 40 x 80-foot wind tunnel facility assisted ARL and its partners conduct unique experiments relating to rotorblades.

Prediction and control of Army helicopter performance and acoustic emission is a long-term ARL goal.

The flowfield about Army rotorblades is complicated by a rich variety of complex flow phenomenon, including supersonic flow on the advancing side of the rotor, dynamic stall, and the formation of a vortical wake with which the rotor flies in close proximity.

Under DARPA support, ARL has developed validated physics-based computational fluid dynamics techniques to more accurately predict these flowfields. The advances incorporated into these codes include the incorporation of advanced turbulence models that do not involve the Boussinesq approximation (which models turbulence stresses using an eddy viscosity, an assumption known to break down in complex flows); the use of adaptive mesh refinement and higher-order differencing to better resolve the fine vortical scales of this flowfield; and high performance computing.

These models were developed and then validated against existing UH-60 and BO-105 helicopter data.

Of course, the ultimate test of any prediction methodology is when it applied to a new configuration for which the data is not available to the code developer.

During the last year, a joint DARPA/AMRDEC program has supported a unique experimental demonstration of the efficacy of smart-materials based flap deflection for acoustic emission reduction in the NASA Ames quiet 40 x 80-foot wind tunnel.

The computational methodologies developed previously were used to predict the experimental results prior to this experiment, and these computational results compared very favorably against the experimental results once they were obtained.

Prediction, control and reduction of rotor blade acoustic emission offers great potential for improved survivability from lower probability of detection, improved reliability from reduction of acoustically caused physical stresses, and improved crew performance by reduction of current high noise levels.

Quantum Imaging/Ghost Imaging

ARL-funded researchers have made impressive strides toward exploiting quantum entanglement for imaging. A key element of "Discovery and manipulation of new quantum phases of matter," is to enable exotic quantum phenomena to be exploited for unique technological opportunities. In ghost imaging, by measurement of, for example, the properties of one photon from an entangled pair (this photon perhaps has never even left the lab), one can image an object that has interacted with the other photon. Potential applications include covert imaging, non-destructive imaging, subwavelength imaging, and potentially ultrasensitive ways to detect but avoid triggering munitions. Ghost imaging, one of four major components of the ARL Quantum Imaging MURI in its fourth year, has now successfully been demonstrated for opaque objects.

ARL has been actively involved in the MURI from the very beginning, and established a strong collaboration with a few of the key MURI players. Particularly important has been ARL's collaboration with the University of Maryland, Baltimore County. (Other components of the MURI dealing with ghost imaging are at MIT and Rochester.) The MURI-ARL team has recently been able to demonstrate "ghost imaging" of opaque objects. In the accompanying illustration we see a ghost image of a toy soldier they obtained with a camera aimed at the light source (a chaotic laser), rather than at the toy soldier itself. A second sensor (basically a light meter) was aimed at the object. The image of the toy soldier was obtained by combining the light source spatial information from the camera and the second sensor measurement (just intensity and not spatial resolution) of the scattered and reflected quanta of light (photons).

This experiment provides for the first time a proof-of-principle practical method of ghost imaging in a form that has many civilian and military applications, and also contributes to fundamental quantum physics understanding. One example of that understanding is that there has been an interesting and ongoing split within the community as to what the underlying physics of ghost imagining is: is it classical or is it quantum? A collaborator at the University of Maryland, Baltimore County, is the strongest proponent of the answer "it is quantum." However, other groups have maintained, and this experiment has shown, that certain features of ghost imaging survive with classically-correlated photons. However, other members of the ARL MURI team have shown that such classical ghost imaging does not have the full range of abilities that quantum ghost imaging has. At a minimum, the quantum version has higher resolution. Moreover, it has just been recognized that the quantum version can be used to image at alternative wavelengths. One of the entangled photons in the pair could be in the IR, while the one being stored and imaged with could be in the visible.

Ghost imaging may help lead to improved satellite imaging of the earth's surface, provide better imaging of targets through partially obscuring smoke and clouds, and enable improved communication of images. The collaborative work of ARL and the MURI team is reported in Physical Review A: Meyers et al., "Ghost-imaging experiment by measuring reflected photons," Apr. 8, 2008.

A Ghostly Image

ARL-funded researchers are making great strides in exploiting exotic quantum phenomena.

Mobile Ad Hoc Network (MANET)

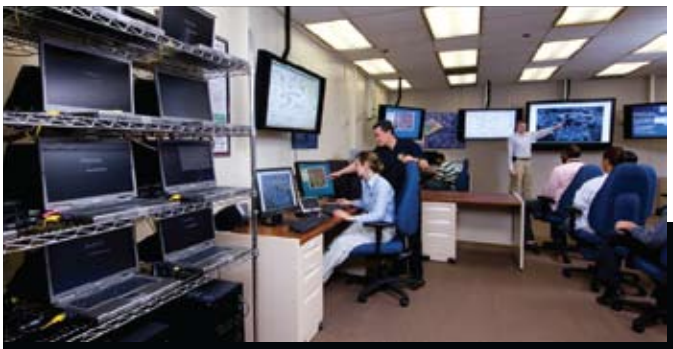
The Future Combat Systems (FCS) architecture relies on a reliable and secure network to enable the Soldier to accomplish the mission. Currently, the state-of-the-art in network science is a limited understanding of the structure dynamics, appropriate metrics, and interactions between the physical, information and cognitive network.

We cannot predict with confidence that the networks being designed will meet the mission needs. Existing tools to study sensitivity, robustness, and relative efficiency of network designs are inadequate. In FY08, ARL conducted research in the Physical, Media Access Control, and Network (PHY/MAC/NET) layers interaction and developed a greater understanding of the inter-relationships between power control, network topology and routing. Using this research, ARL developed abstractions of the PHY, MAC, and NET layers using theoretical models.

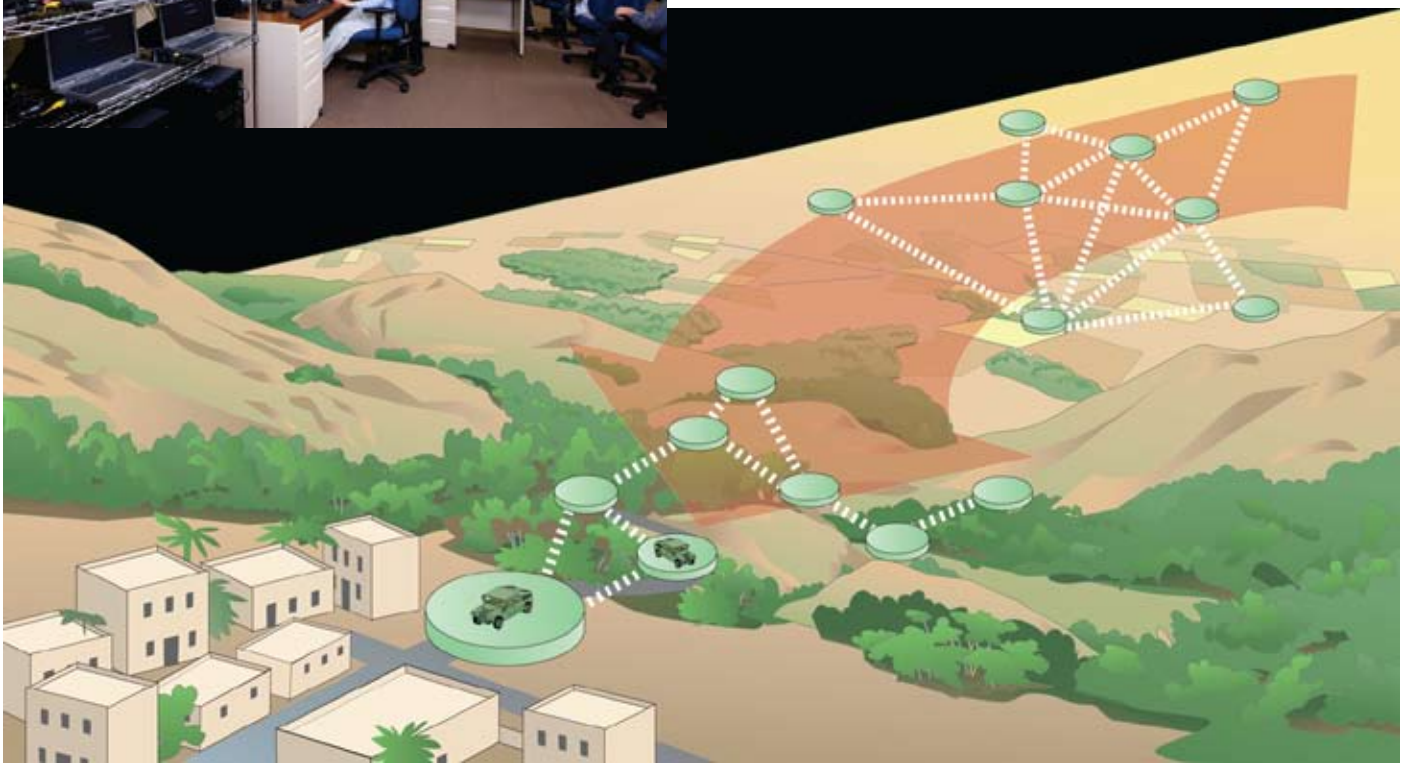
ARL developed scaling laws for heterogeneous networks and an enhanced security framework for reasoning about dynamic security policies.

This research will lead to a higher degree of fidelity and will enhance the reliance on the network supporting FCS and the Soldier.

This technology is in support of the CERDEC Tactical Information Technologies for Assured Networks (TITAN) ATO.



ARL researchers are gaining a better understanding of networks, which will ultimately lead to a higher degree of dependability in supporting FCS and Soldiers.



Battlespace Terrain Reasoning Awareness

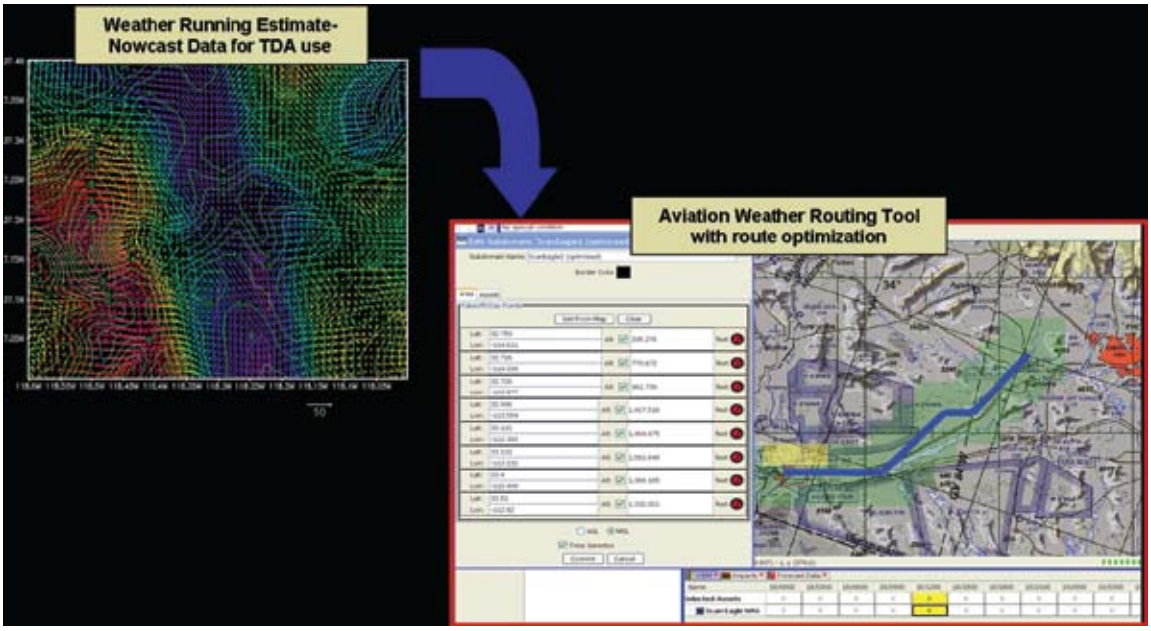
The Battlespace Terrain Reasoning Awareness-Battle Command (BTRA-BC) project between ARL and the Corps of Engineers Labs is developing the Army's future mission planning system that can optimize ground maneuver routes and mission timing to neutralize or avoid threat, terrain and weather hazards while maximizing speed and tactical advantage.

The major focus is on the development and delivery of weather impact rules for BTRA systems and missions and transitioning of the software through ERDC/CERL for integration into the BTRA-BC products.

ARL is responsible for introducing weather through its impacts on military weapons systems and operations.

In FY08, ARL's Aviation Weather Routing Tool (AWRT) was modified to improve its capabilities/applications for specific use in BTRA-BC.

In addition, ARL's Weather Running Estimate-Nowcast (WRE-N) capability was enhanced and refined in order to provide output at horizontal grid point resolution as low as one kilometer for depicting all localized weather conditions and weather impacts effecting BTRA-BC ground and air operations in a given domain.



Weather Impacts – Decision aids and routing for the Battlespace Terrain Reasoning Awareness-Battle Command project for optimizing ground-maneuver routes and mission timing.

Intelligent Optics

High-resolution, real-time, reliable multi-video stream transmission over wireless links is essential for many future Army, Special Operation, and Air Force battlefield scenarios, including reconnaissance missions, missile guidance, and command control.

Because of insufficient bandwidth and high error rates, existing wireless radio frequency (RF) links can only support video data transmission from a single relatively low-resolution video camera.

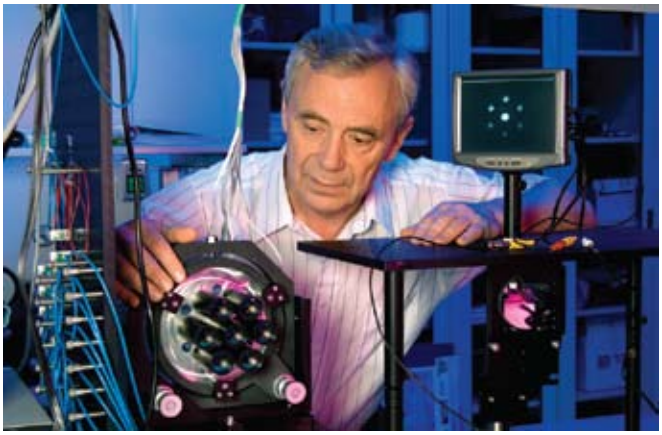
RF links are not viable for real-time secure transfer of video streams from high-resolution cameras hand-mounted or mounted on ground or airborne platforms. An alternative to wireless RF is free-space laser communication technology, which offers high speed, mobile, secure point-to-point communication capabilities for a variety of ground and air battle scenarios.

The Scalable Phase-locked Adaptive Communication Element (SPACE) system concept allows the design of very compact, robust, inexpensive, and low-power laser communication modules capable of increasing data rates by orders of magnitudes with an overall reduction in cost.

The new scalable optical communication architecture provides reliable and secure space communications, which can be used for various DoD missions.

In FY08, ARL's Intelligent Optics Laboratory team developed the adaptive optics hardware for the Army high energy laser weapons applications. A low-energy version using a target-in-the-loop configuration was tested and a laboratory experiment supported the evaluation of seven sub-apertures which were controlled by tip/tilt and phase locking capabilities.

Mathematical methods and computational approaches for wide field of view anisoplanatic imaging of extended targets were developed.



Successful tests of the seven channel SPACE system proved that this is a viable and greatly superior approach to a scalable architecture for Army high speed laser communications. This research supports a Communications-Electronics Research, Development and Engineering Center (CERDEC) TPA centered on developing a scalable laser communications architecture that is a viable candidate for long distance communications through atmospheric turbulence.

The research also supports a synthetic imaging development for CERDEC's Night Vision and Electronic Sensors Directorate (NVESD). An outcome of the research is the development of the concepts of both high resolution conformal phase locked imaging and synthetic imaging.

A computer program was transferred to NVESD that incorporates synthetic imaging capabilities.

Intelligent Optics - Dr. Mikhail Vorontsov with the seven aperture Adaptive Photonic Phase-Locked Elements (APPLE) scalable laser cluster.

Human Dimension

Human Factors Analysis of Mine Resistant Ambush Protected (MRAP) Vehicle Seating and Restraint Systems

Improvised Explosive Devices (IED) remains a primary threat to Soldiers and Marines fighting the War on Terror. To counter this threat the Mine Resistant Ambush Protected (MRAP) family-of-vehicles is currently being fielded. Several MRAP vehicle variants are being evaluated by the US Army Research Laboratory. ARL was tasked to analyze the MRAP vehicle seating and restraint systems and to make design recommendations based on concerns expressed by Congress and Soldiers in the field.

Soldiers have expressed concerns regarding their inability to reach controls while restrained, due to either poor seat design or insufficient restraint adjustability. To address these concerns an analysis was performed using human figure modeling, supported by user survey interviews and experimental subject testing. The assessment of seat and seat belt usability for the user population included extreme accommodation with equipment loads, and identified improvements in seat belt wear, and seat and equipment layout. The recommendations will lead to improved vehicle egress, increased Soldier accommodation, and reduced injury possibility. ARL is integrating the improved seat and seat belt design characteristics into MRAP systems, resulting in increased Soldier survivability and equipment usability.

ARL's results are being used in the decision making process by the JMPO to field state-of-the-art seating and restraint systems for MRAP vehicles that offer superior protection and accommodation to today's Warfighter, fully equipped with the tactical mission equipment that Warfighters wear and carry into battle. These seating and restraint systems are setting the standard for future tactical wheeled vehicles and providing short term solutions for currently fielded vehicles.

Human-figure modeling is assisting ARL analysts perform research into restraint systems for the MRAP leading to more functionality and increased Soldier survivability.

Improving Warfighter Safety

ARL's analysis of MRAP vehicle seating and restraint systems is helping provide superior protection to today's Warfighter.

Enhanced Joint Tactical Communications on the Battlefield

One of ARL's missions is to ensure that Warfighters can effectively communicate on the battlefield. Next-generation, software-defined radios provide advanced functionality that will allow a single radio to operate multiple legacy radio waveforms.

A legacy radio, such as a Single Channel Ground and Airborne Radio System (SINCGARS) or Enhanced Position Location Reporting System (EPLRS), is limited to operating a single waveform, whereas a Joint Tactical Radio System (JTRS) set is capable of operating multiple waveforms by simply turning a knob from one preset to another or by choosing a different preset from a menu. Presets, which contain all the system parameters necessary to operate a particular waveform on a JTRS set, are a new functional concept that requires careful planning and management to establish and maintain communication.

To manage the complexity inherent in this technology and make it seamless to the Warfighter, ARL collaborated with the JTRS Handheld, Manpack, and Small Form Fit Product Manager and the TRADOC Capabilities Manager for Tactical Radios to bring the radio's system designers and developers to the Warfighter.

A Soldier reports his present location on a tactical radio. Validating results of early research and obtaining Warfighter evaluation of radio components is critical.

ARL researchers explain a hardware design issue to a Soldier. This collaboration brings the radio's system designers and developers to the customer — the Warfighter.

Warfighters from the Air Force, Army, Marine Corps, and Navy participated in four user studies to ensure that the JTRS sets would meet their tactical needs. The initial user study identified mission essential communications functions, validated operational requirements and identified gaps, revealed precisely how radios are being used in different operational environments by the different military services, and identified what is working well and what is not on radios currently in use.

Subsequent studies focused on validating results of the earlier research and obtaining Warfighter evaluation of the radio's graphical user interface and hardware components using software simulations and manpack radio technology demonstration units. Warfighters contributed to the radio's design by identifying usability issues and suggesting mitigations to resolve them, creating a prioritized menu hierarchy that organized access to radio functions to best support tactical usage, and by defining a set of icons and text labels for use on the radio's keypad.

Use of this Warfighter-centric iterative design process will help ensure that JTRS Warfighter-machine interactions will facilitate tactical communications under the hostile and highly stressful conditions encountered on the battlefield.

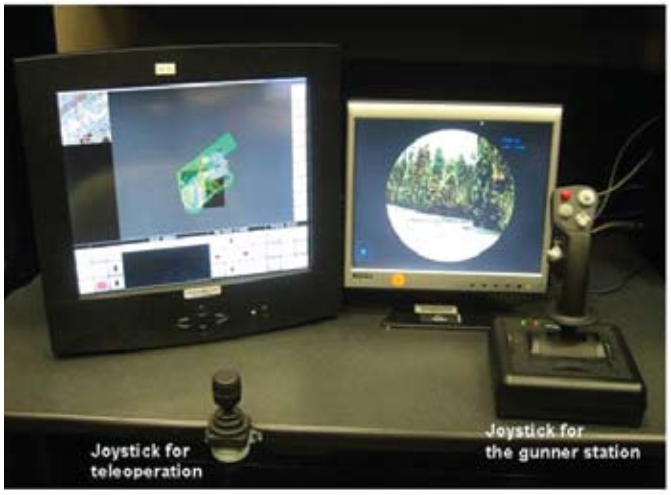
Effectiveness of Concurrent Performance of Gunnery and Robotics Tasks and Effects of Cueing in a Simulated Mounted Environment

The Army Research Laboratory simulated a mounted crewstation environment and conducted a series of three experiments to examine the workload and performance of the combined position of gunner and robotics operator in a multitasking environment. The robotics tasks involved managing a semi-autonomous ground robot or teleoperating a ground robot to conduct reconnaissance tasks. ARL also evaluated whether aided target recognition (AiTR) capabilities (delivered either through tactile or tactile plus visual cueing) for the gunnery task might benefit the concurrent robotics and communication tasks and how the concurrent task performance might be affected when the AiTR was unreliable (i.e., false alarm-prone or miss-prone).

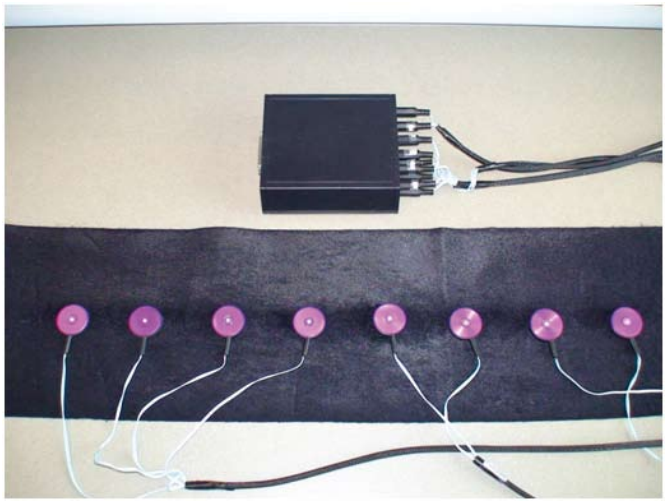
Results showed that participants' gunnery task performance degraded significantly when they had to concurrently monitor, manage, or teleoperate a robot compared with the gunnery-single task condition. When there was AiTR to assist them with their gunnery task, operators' concurrent performance of robotics and communication tasks improved significantly.

However, there was a tendency for participants to over-rely on automation when task load was heavy, and performance degradations were observed in instances where automation failed to be entirely reliable. Participants with lower attentional control skills were especially reliant on the automated systems, even those with high miss rates. On the other hand, those with higher attentional control tended to rely on their own multitasking skills and distrust false alarm-prone automated systems, which actually resulted in sub-optimal task performance.

Participants' spatial ability was consistently found to be a reliable predictor of their targeting task performance. Additionally, low spatial ability participants indicated that they preferred visual cueing over tactile cueing, and conversely, high spatial ability participants favored tactile cueing over visual cueing. Potential applications of our findings include personnel selection for robotics operation, robotics user interface designs, and training development.



Shown are the Tactical Control Unit (left) and the Gunnery Station (gunner's out-the-window view) (right).



The tactile cueing system, in conjunction with the Tactical Control Unit, allows a robot operator/gunner to multitask.

These studies were funded by the Robotics Collaboration Army Technology Objective, and conducted with assistance and facilities of the RDECOM Simulation and Training Technology Center (STTC), located in Orlando, Fla. Research results were published in Ergonomics and will also appear in Military Psychology.

Lethality

Technology Suite for Affordable Precision Munitions

The Army fully realizes the tremendous capability that precision munitions can bring to the battlefield. In fact, the Army Modular Force of the future relies heavily upon precision fires to achieve lethality overmatch at greater ranges and with fewer platforms.

Central to this vision is the ability to engage and defeat targets at extended ranges while limiting collateral damage to an absolute minimum. Such missions dictate the need for a high degree of precision at the system level.

To enable this capability, ARL utilizes system effectiveness models to isolate the technology investments that will provide the greatest return and develops appropriate research programs around these. These research thrusts include Unsteady Aerodynamics, described later in detail, Reduced State Guidance, Navigation and Control Techniques, and Novel Control Mechanisms.

The reduced state Guidance, Navigation and Control (GN&C) solutions utilized inherent ballistic accuracies to the fullest extend possible, and required only small trajectory perturbations to result in significant overall reductions in dispersion. These included developing various forms of vehicle state estimators, such as non-linear Kalman filters, and coupling these with simplified navigation schemes such as trajectory trackers or impact point predictors.

To provide the inputs necessary for accurate state determination, unique constellations of devices (inertial, magnetic and GPS) continue to be developed. Lastly, requirements for the maneuver mechanisms themselves dictated minimal size, power, mass, and complexity, in addition to affordability.

In response, ARL has developed a novel GN&C control system, in combination with a unique actuator configuration. This combination of technologies resulted in a solution that is able to meet a set of realistic user requirements at low-cost.

This technology will enable the Army to exploit precision indirect fires across the future battlefield.

Concept for Very Affordable Precision Projectile (VAPP) including unique canard actuator mechanism.

Low-cost Solutions for Future Battlefields

Ballistic Trajectory Guidance, Navigation, and Control: Deliver reduced state ballistic trajectory guidance, navigation, and control algorithms for gun launched munitions

Nonlinear Unsteady Aerodynamics for Affordable Precision Projectiles

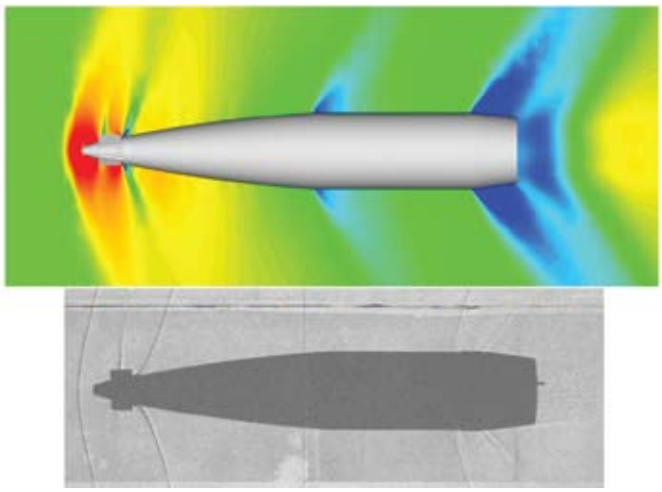
ARL recently has developed advanced Computational Fluid Dynamics predictive technologies to determine the unsteady aerodynamics and flight dynamics of affordable precision munition projectiles.

These methods employ advanced, state-of-the-art techniques and capabilities, including unstructured meshing, advanced turbulence models, and time-accurate techniques to simulate the flow over the complex, unconventional shapes. Precision munitions often utilize nose-mounted control actuators such as drag and spin brakes, de-spun and dithering canards, and de-spun movable noses sections.

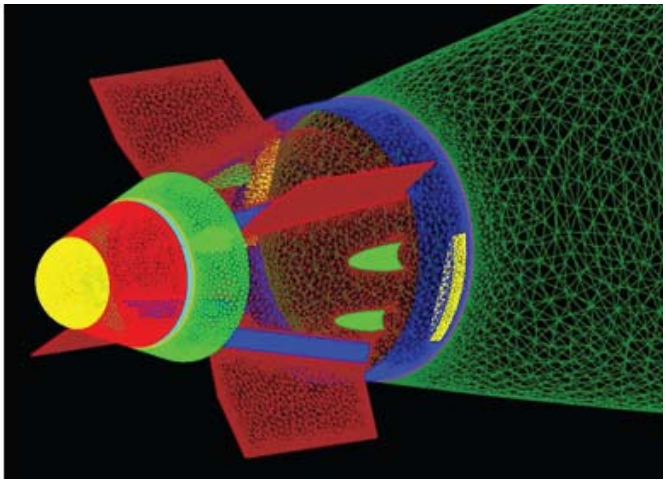
These revolutionary technologies were developed and demonstrated in the form of the precision guidance kits, and course-corrected fuze (CCF). Highly-accurate aerodynamic assessments are required to reduce the burden on the guidance, navigation and control system and improve system accuracy.

One of the primary design challenges for CCF and other precision munition systems are in the accurate characterization of the aerodynamic behavior associated with these new and unconventional nose shapes.

The computational methods were applied to several precision munition concepts under investigation by the Army, such as the CCF concept for a 155-mm



Comparison of computed contour (top) with a spark shadowgraph (bottom) M = 1.1, nose 3.



Unstructured surface mesh for the nose 3 configuration.

artillery application shown below. Time-accurate numerical computations were performed using an advanced Navier-Stokes computational procedure to predict the unsteady flow fields associated with the pitching and rolling motion of a spinning projectile with selected CCF designs and the results validated with the data obtained from limited free-flight tests.

This research provided critical fundamental understanding of the flow physics required to evaluate new designs of complex aerodynamic configurations of precision munitions using novel control devices.

These tools are also being applied to a joint ARL–ARDEC program, managed by PM-CAS, to develop and flight-test a low-cost, 105-mm guided artillery projectile for the 105-mm lightweight howitzer.

Metastable Polymeric Nitrogen: A Disruptive, High-Energy, Green Energetic Material

The recovery of metastable polynitrogen (PN) materials from high-pressure/temperature quenches are being investigated at the Army Research Laboratory.

Many simple molecules, such as N2, potentially form extended molecular solids under extreme conditions.

These have energy capacities an order of magnitude greater than current materials in addition to being an environmentally friendly solution.

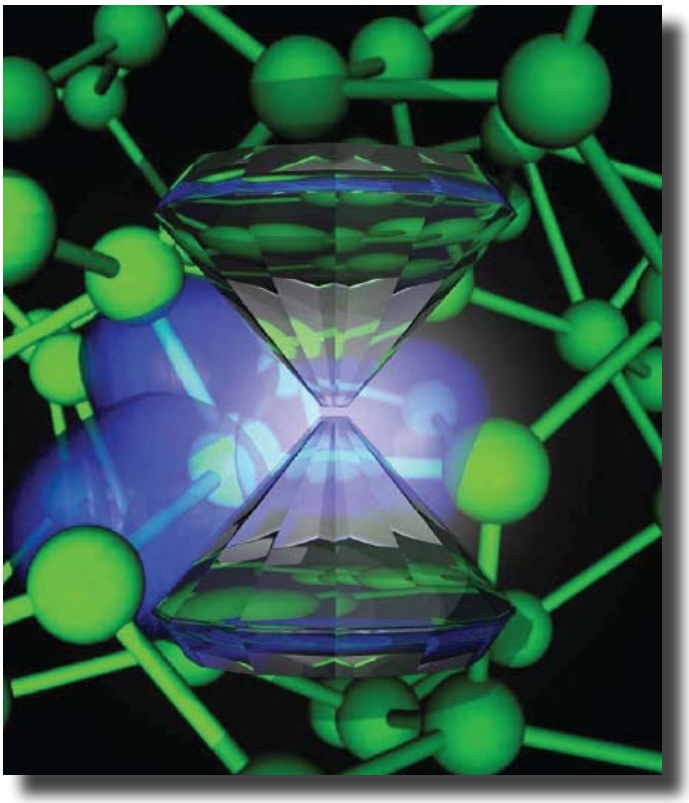
Diatomic nitrogen is particularly interesting because of the uniquely large energy difference between that of the single bond (160 kJ/mol) and the triple bond (954 kJ/mol).

The recovery of PN quenches at ambient conditions implies the possibility that the dynamic release of energy can be tailored through external stimuli resulting in detonation or burning.

A novel high-pressure method has been employed to investigate the chemical and physical modifications that occur in an uncommon nitrogen/hydrogen alloy that may offer a viable route to stabilize the quench. Near 35GPa, a new phase was observed which showed strong signatures of a singly-bonded nonmolecular phase of nitrogen.

Upon decompression, the nonmolecular phase remained stable at room temperature to 6GPa, nearly an order of magnitude greater than previous recovery attempts.

Structural analysis has indicated a cyclic N6 structure with the hydrogen encapsulated within. Strong resonance bonds between the nitrogen and hydrogen stabilize the phase.



Using a diamond anvil such as the one depicted above, a novel high-pressure method has been employed to investigate uncommon nitrogen/hydrogen alloys.

Further experiments are underway to control its metastability below 6GPa. While still in its early stages, the technologies developed in this program will have important implications in the design of future energetic materials.

Autonomous Aerial System Technologies

ARL has been building the capability to design, build, and experiment with unmanned aerial systems (UAS).

One of the growing and more promising fields is small-scale UAS and micro air vehicles, where it is imperative to add increased autonomous functionality in a very small flight package.

One of the keys to developing vehicles with ever increasing autonomous capability is to have the ability to perform basic research with components that are well known and defined, but can be modified to operate with new equipment, systems, or algorithms.

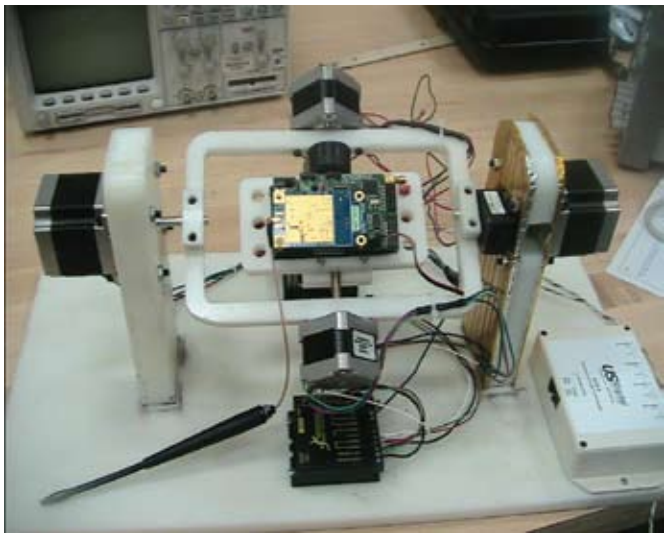
Researchers from ARL and ARL-funded academic partners at the University of Alabama, Huntsville, and Jackson State University, have been working together to build this capability that expedites research for the next generation small-scale UAS.

During FY08, ARL researchers purchased equipment and developed tools to conduct small-scale UAS experiments, including microcontroller autopilots and flight control software.

Microcontroller-based autopilots were built, calibrated, and programmed for a small two-foot diameter rotor helicopter. In addition to the autopilot hardware, researchers developed a hardware-in-the-loop simulation tool utilizing a highly accurate and compact gimbal.

The gimbal, autopilot, and flight simulation software linked together allow researchers the opportunity to perform valuable autonomous flight control algorithm research without the vehicle ever leaving the ground.

In addition, hardware research of the autopilots and associated algorithms and sensors can be performed on a long-term basis with greatly reduced cost and effort.



Gimballed experimental apparatus supports hardware-in-the-loop simulation.

Micro autopilot and associated electronics packages on a typical small scale unmanned aerial vehicle.

Condition-Based Maintenance for Apache Aircraft Bearings

Over the past 18 months, research by ARL has collaborated with the U.S. Army Aviation and Missile Command (AMCOM) to assess if vibration monitoring algorithms as employed on the Army's Vibration Monitoring System can be implemented with sufficient confidence to extend the existing Time-Between-Overhaul (TBO) usage limits for some Apache flight-safety critical mechanical components. A grease-lubricated bearing used on the Apache APU clutch system was selected as a candidate for extending the TBO.

ARL Degraded Grease Bearing Rig - Condition of an Apache clutch bearing cage and balls after extended running time. The brown deposit shown is degraded grease that, when new, has a red coloring.

One of the bearing fault modes that needed to be investigated was the chemical degradation of the lubricating grease. A special test rig was developed to operate the bearings in a heated environment, the heat allowing for accelerated rates of the chemical processes involved.

Bearings with degraded grease were provided to the Redstone Aviation Propulsion Test and Research (RAPTR) team where the bearings were operated in the clutch assembly for further proof of the capability of the bearing and the capabilities of the Vibration Management Enhancement Program system.

A second bearing fault scenario that needed to be investigated was rotordynamic whirl that could occur because of bearing wear. ARL created a special mix of the aircraft-qualified grease with coarse silicon-carbide powder and fine aluminum-oxide powder.

This mixture was successful in providing a greatly accelerated but controlled wear rate. The RAPTR team reported that the seeded fault bearings provided by ARL were a great success allowing them to capture the transition of the operating condition to the whirl mode.

Based on this research, a formal extension of the bearing overhaul time (from 1,000 hours to 1,250 hours) has been approved.

The TBO will further be extended to 1,500 hours pending data that will come in using a "lead-the-fleet" approach.

Near Autonomous Operation of Unmanned Systems

Future unmanned systems will operate as an effective member of the combat team, able to operate hand-in-hand with Soldiers conducting multiple military missions. To achieve this goal, ARL and members of its Robotics Collaborative Technology Alliance have undertaken advanced research in three key technologies: perception, intelligence, and human-robot interaction. ARL is developing technology to permit unmanned systems to accurately understand the environment employing a broad vocabulary of labels for objects and activities. It is developing planning tools that will permit unmanned systems to rapidly plan activity in dynamic environments, taking into consideration likely actions by friends, opponents, and non-combatants, much like a Soldier would do. It is developing technology that will permit Soldiers to manage multiple unmanned systems without significantly compromising their own security and situational awareness.

During FY08, ARL developed improved algorithms employing multiple sensor modes to detect, classify, and track pedestrians and vehicles. It has developed algorithms for the identification of common road features, such as stop signs, that will be required by unmanned systems operating on public road networks. It has developed rapid path planning techniques that will enable unmanned systems to operate safely on roads and highways with other vehicles. It has improved techniques for perception of objects at ranges of a kilometer or more that will aid the vehicle to autonomously plan maneuver in a more tactically intelligent fashion. It has conducted technology assessments to develop quantitative performance data and transitioned the resultant information and technology to both advanced development and materiel acquisition programs, such as those being conducted by the Tank Automotive Research, Development and Engineering Center and PM Future Combat Systems.

Unmanned vehicle autonomously overtaking manned vehicle in accordance with standard driving rules.

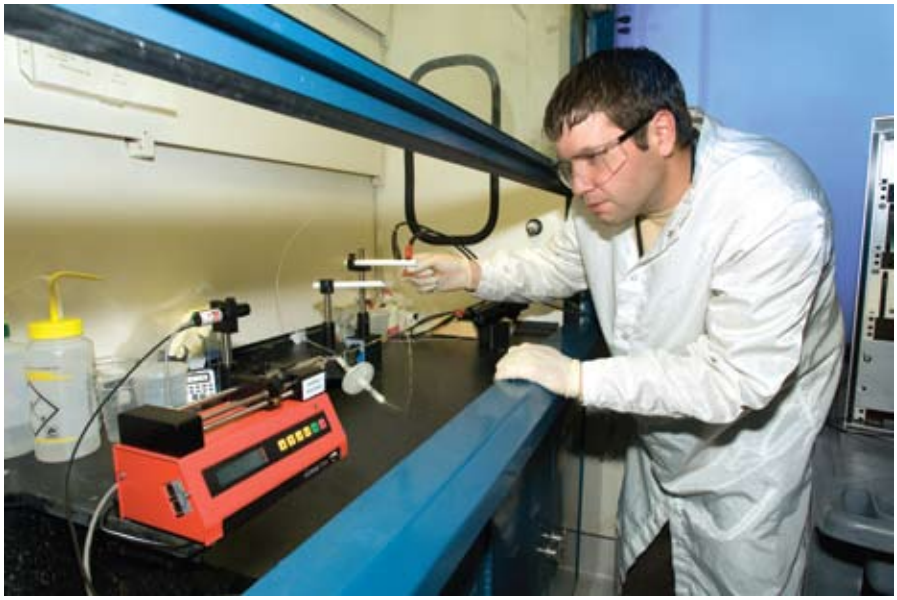
Experimentation to assess performance of vehicle perception and planning with a high density of obstacles.

Power and Energy

Power MEMS

The Army has a need for small portable power systems to support a range of operations from Soldier power to Unmanned Aerial Vehicles (UAV) and Unmanned Ground Vehicles (UGV) applications.

The use of liquid-fueled power generation for these applications has the potential to provide longer run times in a smaller and lighter package than current battery based systems. While these generators have the potential to outperform batteries, current technology limits system run time and reliability due to inefficient fuel-based energy conversion and inefficient balance of plant components.



ARL researchers are busy developing components for UAVs and UGVs to enhance energy conversion while reducing consumption.

To improve system efficiency and reliability, ARL is developing components based on Micro Electro Mechanical Systems (MEMS) technology that enhance energy conversion efficiency while reducing power consumption and improving functionality in balance of plant components.

ARL, in collaboration with Yale University, is improving combustion efficiencies and reliability through continuous improvements in electrospray fuel atomizer technology. Key FY08 electrospray improvements are a two-fold increase in liquid flux to >400 ml/hr/cm^2 while reducing droplet sizes to a uniform 5 µm and a forty-fold increase in nozzle density to 11,000 nozzles/cm^2.

MEMs Based Atomizer.

These improvements were enabled by the microfabrication processes developed at ARL and allow for smaller, more efficient atomizers which require less then 10 mW/ml/hr of fuel delivered to the system.

To improve balance of plant components ARL is developing microfabricated pumps and motors that utilize microball bearings for support. ARL demonstrated the first fully encapsulated ball bearing race assembly fabricated using stainless steel microballs and a silicon housing/rotor capable of speeds greater than 80 krpm with little to no wear.

A micromachined pump employing the microball bearing demonstrated flow rates up to 80 ml/hr with a peak liquid pressure rise of 1.2 psi. In collaboration with University of Maryland, a rotary micro motor utilizing the microball bearing was demonstrated with controlled positioning and speeds in excess of 2,000 rpm.

These demonstrations represent a milestone break-through for microscale fuel delivery components, with potential application in high density, Soldier and Micro Air vehicle power sources for power levels of 100 watts or less.

This work is part of a joint ATO with CERDEC and NSRDEC. There is also a TPA with CERDEC involving the MEMS fuel injector.

Battery-to-Bus Converter for FCS

The Army Future Combat Systems (FCS) utilizes an advanced hybrid electric system that must deliver power for communications, mobility, survivability and lethality. The power system includes a rechargeable bank of 300-volt batteries, which are constantly charged by the engine, to provide energy storage and burst-mode power for the vehicle. Power is transmitted between the 300-volt batteries to the vital components using a 600-volt DC bus architecture requiring compact and efficient DC-DC converters.

ARL has developed and demonstrated an advanced compact bi-directional DC-DC converter using newly developed Silicon Carbide (SiC) technology combined with new thermal management and packaging techniques. The system has been demonstrated at both the ARL in-house power components test bed and at the TARDEC Systems Integration Lab (SIL). ARL's DC-DC converter technology demonstrated the highest power density and efficiency that operates at the FCS specified 80 degrees Celsius (C) inlet coolant temperature, better than any other available system.

ARL researchers have successfully developed a DC-DC converter using new Silicon Carbide technology providing superior power density and efficiency for the Army's Future Combat Systems.

As a result of these demonstrations, the PM FCS Manned Systems Integration office has indicated support for a four-year joint ARL/TARDEC program, with ARL as lead, for providing high power components to FCS MGV systems that operate at a more stringent, 100 degrees C, inlet coolant temperature. The next generation converter under development at ARL boasts increased temperature operation exceeding 100 degrees C and a twofold increase in power density through the use of SiC power switches and advanced magnetic materials for passive components.

ARL Helps DoD Highlight Advances in Wearable Power

A significant challenge for the military research and development community in the next decade is providing the portable power necessary to fuel a variety of applications for the Warfighter, ranging from computing, environmentally-controlled clothing, radios, and night vision goggles. Because expanded capabilities create an expanded need for power, the Department of Defense (DoD) is heightening its efforts to improve and transition advances in wearable power technology.

The term "wearable power" encompasses technologies designed to make higher levels of more efficient and lightweight power available to Soldiers on the battlefield. To this end, DoD held held the Wearable Power Prize Competition at the Marine Corps Air Ground Combat Center, 29 Palms, Calif. The program included 169 registered teams, 20 of which participated at the competition at 29 Palms from Sept. 21 - Oct. 4, 2008. The competition was sponsored by Under Secretary of Defense for Acquisition, Technology and Logistics John Young and Deputy Under Secretary of Defense for Laboratories and Basic Sciences William S. Rees.

In addition to ARL's contributions to the winning team, John Hopkins of ARL's Sensors and Electron Devices Directorate served as the program manager for the competition. He emphasized that the competition would provide many benefits to the U.S. military.

"The issue of wearable power is a very tough problem," noted Hopkins. "You don't necessarily see power on the battlefield. Because it's an enabling technology, and not an end item, it might not be the first problem you think of.

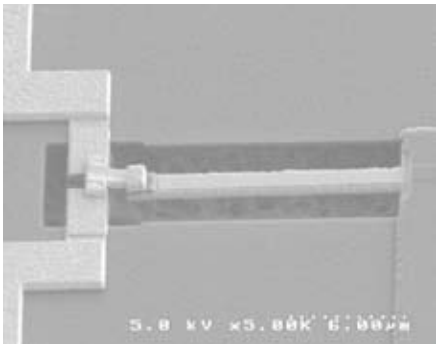
"Part of the impetus for the competition was to increase awareness of this issue," Hopkins continued. "There are a lot of people out there working on wearable power, and the competition helped generate interest in both their efforts and the need for more research."

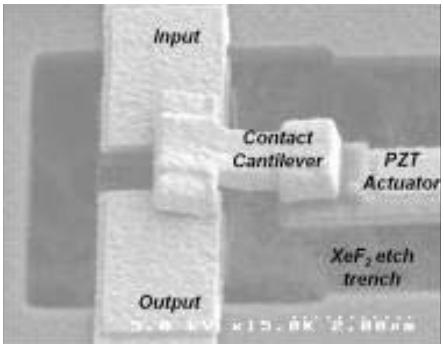
The collaborative spirit extended to the U.S. military's sponsorship and participation in the program. While the Army is the primary customer for the technology, the competition had a tri-service approach.

Sensing

Piezoelectric Nanoswitch

ARL researchers, using ARL's Specialty Electronic Materials and Sensors Cleanroom, have successfully demonstrated the world's first working piezoelectric (PZT) nanoswitch as part of a DARPA seedling effort to create nanoelectromechanical switches (NEMS) to mitigate the high leakage currents within next-generation sub-45 nm node CMOS transistors.





Using an eleven step, aligned electron-beam lithography process, PZT nanoswitches were fabricated using an actuator stack comprised of SiO2/Ti/Pt/PZT/Pt (85/5/50/200/50 nm respectively) with a minimum feature size of 500 nm and 50 nm alignment tolerance.

The multiple-step electron-beam lithography process represents the first realizable demonstration of a piezoelectric nano/micro electromechanical device using such an intricate process.

With a length of 12.5 µm, the normally-closed switch operated at 6 volts with a contact resistance near 50 Ohms. The switching response (minus cable delay) was measured with an "on" (0V) switching time varying from 33 – 43 ns and "off" (6V) switching time varying from 17 – 33 ns. Switch bounce, which can slow the "on" rise time to nearly 500 ns, was observed in some cases and is currently being studied as zero bounce was also observed during switch-cycle tests.

World's First - ARL researchers have successfully demonstrated a piezoelectric nanoswitch in ARL's state-of-the-art cleanroom.

These results demonstrate the feasibility of creating single-nanosecond and subsequently faster nanoswitches using PZT thin films and electron-beam lithography for mechanical logic elements.

The PZT nanoswitch effort is part of a larger-scale DARPA program, Nano Electro Mechanical Switches (NEMS). The NEMS program is targeting the creation of a microcontroller comprised of all mechanical logic elements as a means of creating ultra-low-power (static and dynamic) control elements.

Using PZT MEMS actuators with lengths of 125 µm, initial feasibility of low-voltage inverters, NAND gates, and ring oscillators have also been demonstrated using PZT switches as a building block for mechanical logic elements.

The ultimate goal of the program is to produce nano-scale, low-power, all-mechanical logic operating with clock frequencies in excess of 10 MHz at 1 volt for energy efficient computing and integrated control of PiezoMEMS-based phase shifters and actuators for mm-Scale Robotics.

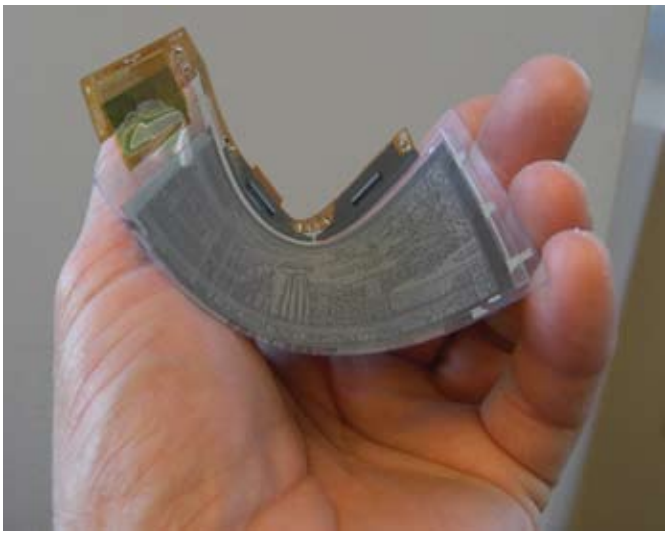
Flexible Reflective Displays

In an effort to accelerate the development of commercial flexible displays so that they might be available to meet military needs, the U.S. Army established the Flexible Display Center (FDC) at Arizona State University in partnership with the state of Arizona. The FDC is the first research and development facility in the world to be exclusively dedicated to work on flexible displays and was formed through a Cooperative Agreement with the Army Research Laboratory and is managed in conjunction with the Natick Soldier Research, Development and Engineering Center (NSRDEC) and partnerships across other RDECs including CERDEC and TARDEC. The Cooperative Agreement allows the University, Army, and Industrial partners to work together to achieve a common goal and includes significant participation by a growing list of industrial partners.

ARL flexible display researchers.

Activities at the FDC focus on issues associated with the fabrication of arrays of thin-film transistors on flexible substrates, such as thin stainless steel or transparent specialty polyester. This challenging piece of large-area microelectronics is the critical subsystem that is required to control an array of electro-optical devices to create a digital display. To complete the display, one of three electro-optic technologies being developed by FDC members is integrated with these thin film transistor panels. Ultra-low-power reflective displays can be made using electrophoretic ink from E Ink Corp., located in Cambridge, Mass., or cholesteric liquid crystal films provided by Kent Displays of Ohio. Alternatively, vibrant full-color and full-motion video organic electroluminescent displays can be built using materials and devices from Universal Display Corporation. These technologies were chosen because of their compatibility with flexible substrates, their power advantages, and their maturity.

Palm Sized



The Flexible Display Center is leading the development of a process for making high-performance transistors for flexible displays. These displays are already making their way into unique information systems.

Recently, FDC researchers, working with industrial partners DuPont Teijin Films and E Ink Corp., have developed a process for making high-performance, amorphous-silicon, thin-film transistors on planarized TeonexR PEN films. The FDC process uses a proprietary technique for temporarily bonding the planarized TeonexR PEN film (from DuPont Teijin) to a rigid carrier using a specially developed adhesive. Amorphous silicon circuits are then fabricated with conventional flat panel display manufacturing equipment. LG Displays and Applied Materials (suppliers of 90 percent of the commercial display manufacturing tools) recently joined the FDC. These flexible displays are currently being integrated into unique information systems, and this program has recently been endorsed by the Director of Combat Development at the TRADOC Infantry Center for these novel applications.

Thick Polymer Films for Electro-Optic Laser Protection Shutter

ARL is developing two active fast shutter technologies for use as broadband laser protection as part of the joint ARL, Natick Soldier Research, Development and Engineering Center (NSRDEC), Tank Automotive Research, Development and Engineering Center (TARDEC), and Communications-Electronics Research, Development and Engineering Center – Night Vision and Electronic Sensor Directorate (CERDEC-NVESD), Vision Protection Army Technology Objective (ATO) for FY06-09.

Electro-optic (EO) and Magneto-optic (MO) materials are being exploited to provide broadband protection against nanosecond laser threats. As a crucial step in developing the EO shutter, ARL has demonstrated high efficiency EO poling in thick (~1 mm) samples of an EO molecule (Disperse Red 1) in plexiglass. Poling is the process of orienting molecules using a strong electric field to orient molecules in a polymer host in order to provide enhanced nonlinear optical properties. Although poling in thin films approximately one micron thick has long been known, applying the technique to polymer films approaching one millimeter in thickness (required for a fast laser protective shutter) had not yielded significant poling, until now. Birefringence has been detected in very thick (~1mm) samples made at ARL, which clearly indicates molecular orientation, a first for samples as thick as these. DR1 dye was introduced into a PMMA (Plexiglas) host, fabricated, processed and poled in a 50 kV electric field.

Measurements have indicated a relatively high electro-optic coefficient (r33) of ~ 6 pm/V, quite remarkable for a bulk piece that had not been fully optimized. More recent results from more advanced chromophores (a three-ring tolane copolymer) synthesized by ARL and funded partner NAVAIR-China Lake indicated electro-optic coefficients of ~ 9 pm/V, sufficient to begin fabricating Pockels devices for sensor and eye protection. Other potential applications of this poling breakthrough include high speed EO modulators, and materials for efficient terahertz frequency generation.

In addition to the breakthrough in poling thick EO polymers, ARL has demonstrated a multi-element magneto-optical shutter array, composed of single-domain, thin-film Bismuth Garnate MO material, with a total diameter of 1 cm. The shutter array was optically triggered by a GaAs photo-conducting semiconductor switch (PCSS). TARDEC and ARL, working with TARDEC contractors Boeing and ORA, have developed a gunner's primary sight optical design as part of the above mentioned ATO. The design incorporates the EO and MO shutters, maximizes their protective performance, and extends the protection regime from nanosecond to femtosecond pulses. NSRDEC and ARL are also collaborating on various PCSS designs for ARL's EO and MO shutters as well as NSRDEC's in-house, non-focal-plane protection concepts as part of the ATO. These materials and devices, when optimized, will transition to NSRDEC and TARDEC.

Materials are being exploited by ARL researchers to provide broadband protection against nanosecond laser threats. ARL will ultimately transition these materials to its RDECOM partners when they are optimized.

Family of UGS (Unattended Ground Sensors)

The primary focus of ARL's Unattended Ground Sensors effort is an initiative called the FUGS (Family of UGS). FUGS technology involves development of communications protocols, waveforms, and payload formats to allow disparate UGS manufactured by multiple vendors, across joint services, to interoperate.

C4ISR (Command, Control, Communications, Computer Intelligence, Surveillance and Reconnaissance) On-the-Move, an annual event, is an experimental venue to assess emerging technologies in a C4ISR System of Systems configuration and to mitigate risk for the Future Combat Systems (FCS) and Future Force technologies. One area of ARL's participation included technology experiments related to UGS systems. The specific FUGS activities included the demonstration of interoperability in which ARL successfully networked seven disparate UGS systems with the ARL common sensor radio. These systems included three fielded Current Force systems, a surrogate FCS UGS system and two ARL experimental systems. These sensor systems sent reports and images to an ARL mobile gateway which in turned created a bridge to the FCS network with software to convert the disparate vendor formats to the FCS required format as well as conversion to the communications protocols required by JTRS and SRW.

ARL researchers and Soldiers collaborate closely. This year, ARL successfully networked seven disparate UGS systems with the ARL common sensor radio.

In addition, ARL linked its mobile gateway from the C4ISR OTM exercise at Fort Dix, N.J., with the JFCOM-sponsored exercise Empire Challenge 08 occurring concurrently at China Lake, Calif. A major component of Empire Challenge is DIA's SensorWeb, which is also intended to increase interoperability. DIA SensorWeb and ARL FUGS are complimentary efforts that collaborated to further the interoperability of Unattended Ground Sensor devices and their data flow through U.S. intelligence channels. ARL FUGS data flowed from the C4ISR OTM exercise to the Empire Challenge exercise via a CERDEC provided SATCOM channel. This event marked a significant gain toward increasing interoperability of ISR assets on a global scale. In addition, ARL has demonstrated innovative communications architectures by networking seven different UGS systems through the Common Sensor Radio (also known as ARL Blue radio) and through the use of remote sensor gateways using store and forward techniques. Cross cueing of one UGS system from a disparate UGS system has also been demonstrated.

ARL is presently leading a working group of the UGS community to establish common standards and interfaces for interoperability of disparate systems as well as inter service interoperability. Membership includes Army G-2, INSCOM, SOCOM, DIA, USMC, Navy, AFRL, DEA, EUCOM, PM RUS, PM FCS BCT (NI), DHS and others. ARL has provided technology inputs for UGS architecture, interfaces and standards.

Multi-Service Ballistic Canopy for Military Rotorcraft Protection

ARL has partnered with the U.S. Navy and Bell Helicopter to develop advanced ballistic solutions for rotorcraft canopies.

In 2008, the Army's Aberdeen Test Center demonstrated the successful ballistic performance of a light-weight ballistic canopy developed and built by ARL.

The canopy window was designed to meet a ballistic specification for a Navy customer, who provides expedient armor solutions to current rotorcraft platforms engaged in operations in southwest Asia.

The ballistic window was submitted to Bell Helicopter in Fort Worth, Texas for integration into an aluminum Army AH-1Z model, canopy frame. The integrated window was subsequently mounted to an AH-64 at the Phillips Army Airfield, Aberdeen Proving Ground, and ballistically tested to specifications.

The test results revealed that the design not only met, but exceeded specifications.

The successful prototype results illustrate that the ARL transparent armor program continues to lead development in advanced transparent armor solutions for current and future military needs.

Transparent Armor Technology - ARL will design, fabricate, and deliver transparent ballistic prototype canopy for the AH-1Z Super Cobra.

ARL Leading the Way – Advanced Transparent Armor Solutions for the Future

An AH-1 attack helicopter and impact sites on a canopy that initiated efforts to improve Warfighter protection in rotorcraft.

Transparent SPINEL Armor and Manufacturing Scale Up

While operator visibility is required for vehicle operations, the visibility of occupants through windows normally encourages focused attacks on the occupants. Tactical platforms already exceed design limits for weight, and boosting the ballistic efficiency of transparent armors using traditional approaches is impractical. New technology to meet advancing threats is clearly required. Ballistic experiments on ceramic SPINEL-based armor against advanced threats at Aberdeen Proving Ground have demonstrated multi-hit performance at weights and thicknesses 50-60 percent less than deployed glass-based armor.

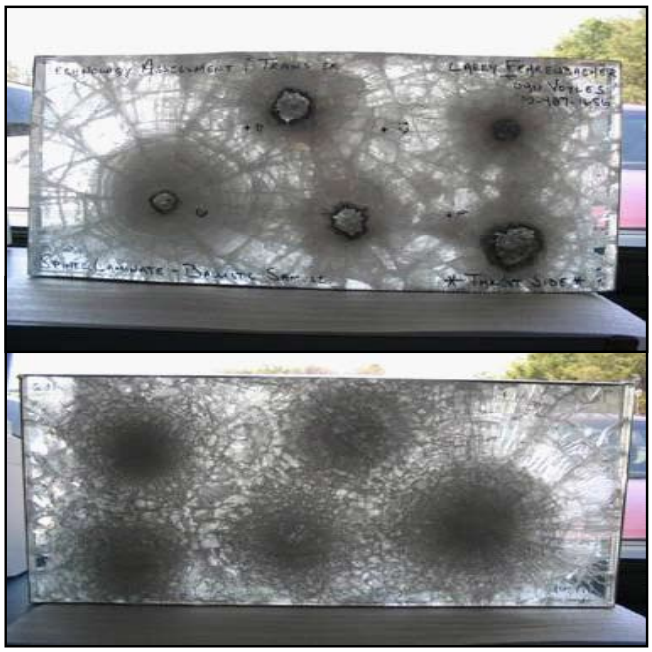
The Army Research Laboratory has also greatly advanced the manufacturability of advanced armor windows by demonstrating:

- Limited rate production of 120 in^2 spinel plates ; cost $19 per square inch in quantities of 500.
- Prototype quantities of spinel plates up to 224 in^2; cost $24 per square inch.
- Demonstrated hot-pressing of multiple plates in one hot-press run.
- Grinding and polishing time and costs reduced by a factor of two.

The improved manufacturability of these highly specialized materials can translate directly into increased production of tactical vehicles and improved protection for operators at affordable costs.

Hot-Pressed Spinel for transparent armor.

SPINEL Armor - Balancing Visibility and Protection


Segmented Spinel-based transparent armor window, 24 x 12 inch, after ballistic testing.

Survivability

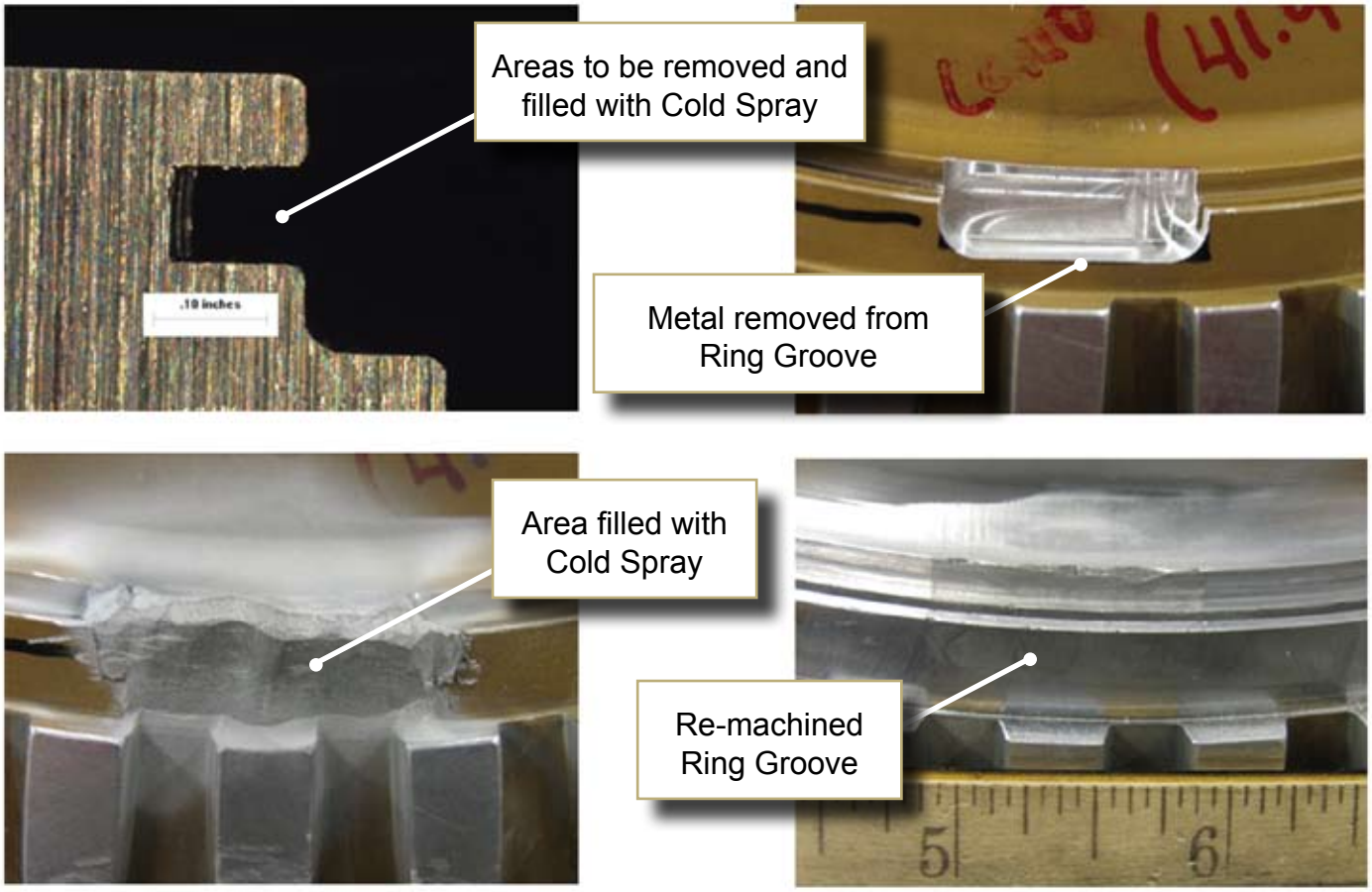
Cold Spray Repair on Mechanical Damage to AH-64 Helicopter Parts

The Army Research Laboratory developed a repair procedure for the U.S. Army Aviation and Missile Command (AMCOM) for the Apache Main Rotor Mast Support using Supersonic Particle Deposition (SPD), also known as Cold Spray.

Corrosion and mechanical damage has rendered approximately 80 parts non-serviceable at Fort Hood, Texas. Each part costs $58,000 for a total of $4.64 million and their absence due to damage resulted in a system readiness issue.

Cold Spray demonstrated that it can replace the material and restore the part. Based on this approach, ARL is drafting a material and process specification and standard operating procedures for the repair.

In addition, ARL will train operators at Fort Hood and Corpus Christi Army Depot, Texas, to ensure transition of the technology.



The photographs above depict the Cold Spray process for an AH-64 Apache Drive Gear. ARL has demonstrated success in replacing the material and restoring the part.

Mine Resistant Ambush Protected (MRAP) Vehicle

ARL is supporting DoD's highest priority program with crew casualty and vehicle damage assessment teams and analytical support for the MRAP I, MRAP Engineering Change Proposal (ECP), MRAP Expedient Armor Program (MEAP), MRAP Ambulance, and MRAP II programs. Each of these MRAP programs is currently conducting testing – simultaneously.

ARL's support begins with vehicle source selection and culminates with Full-Up System Level (FUSL) Live Fire Testing. ARL is collaborating with the test community to ensure that necessary data is being captured to assess crew and vehicle capabilities following each test event as well as gain structural response data to create and improve vulnerability models. The resultant analyses and data are the cornerstones for ongoing crew survivability and engineering analyses to ultimately achieve increased vehicle protection levels for Soldiers in theatre.

ARL is providing crew casualty analyses, vulnerability modeling results and vulnerability reduction recommendations to the MRAP Joint Program Office (JPO) and Army, Marine Corps and DoD evaluators. ARL's insights and analyses have influenced vehicle design changes and helped to determine which vehicles are best suited to the MRAP mission.

U.S. Air Force airmen load a Mine Resistant Ambush Protected vehicle onto a C-5 Galaxy aircraft at Charleston Air Force Base, S.C. ARL's support has influenced vehicle design changes and helps determine which vehicles are best suited for the mission.

Survivability / Lethality Analysis

Future Combat Systems (FCS) System of Systems Common Operating Environment (SOSCOE) Version 1.8.X

Under the Headquarters, Department of the Army (HQDA), CIO/G-6 System of Systems (SoS) Network Vulnerability Assessment (NVA) initiative, and in coordination with PM-FCS, ARL performed vulnerability assessments for the FCS SOSCOE Standard Edition (SE) Version 1.8.1 and SOSCOE Mirco Edition (ME) Version 1.8.

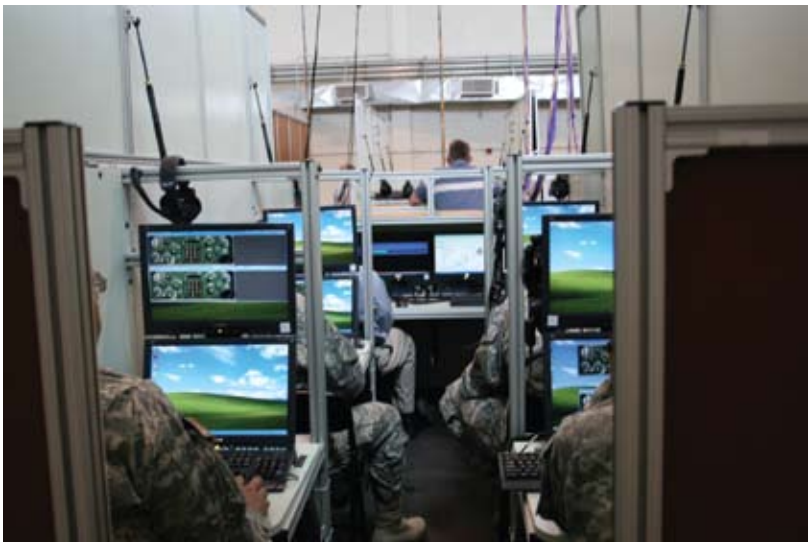
The vulnerability assessments consisted of penetration tests and code analysis performed in the ARL Information Assurance (IA)/ Computer Network Operations (CNO) laboratory located at White Sands Missile Range, N.M.

As a result of this work, PM-FCS has refined their software development process to include robust code analysis and have also implemented recommended mitigations.

The SOSCOE variants (SE, ME and Real-Time Edition (RE)) comprise the middleware that will support communications within the FCS network architecture.

The FCS SOSCOE SE will be deployed in the FCS vehicles (Command and Control Vehicles (C2Vs) and Unmanned Ground Vehicles (UGVs)) and the SOSCOE ME will be deployed in the Unmanned Ground Sensors (UGS). SOSCOE RE, planned for release in FY08, will reside in C2Vs and UGVs.

Future Combat Systems Network testing.



Soldiers play an integral part in Future Combat Systems Network testing.

IED Threat Spurred ARL Support to Aid Rapid MRAP Development

Since the IED threat emerged in Iraq, ARL has worked with a number of partners (National Ground Intelligence Center, Joint IED Defeat Organization, Aberdeen Test Center, RDECs) to develop expedient add-on kits to provide protection.

In April 2007, ARL and the Aberdeen Test Center fielded Interim Frag Kit 6 (IFK6), the first add-on kit that provided protection for the M1114 HMMWV from a lethal class of anti-armor IED. However, these kits were heavy and helped underscore the need for a more robust vehicle.

In response to that need, DoD accelerated production of Mine Resistant Ambush Protected (MRAP) vehicles in large numbers and ARL began adapting the IFK6 technology to the MRAP base armors and hulls.

An International Category II Mine Resistant Ambush Protected (MRAP) vehicle runs a test course at the Developmental Test Command's Aberdeen Test Center. Fielding MRAP vehicles is a key Army priority.

At the same time, ARL is supporting MRAP research in areas of development outlined in more detail in other sections of this Review. This includes human factors analysis of MRAP vehicle seating and restraint systems to improve vehicle egress, increase Soldier accommodations and reduce injury possibility. ARL's recommendations will improve seat and seat belt design to increase Soldier survivability and equipment usability.

ARL is also supporting the MRAP program with crew casualty and vehicle damage assessment teams and analytical support for the MRAP1, MRAP Engineering Change Proposal, MRAP Expedient Armor Program, MRAP Ambulance and MRAP II programs. ARL's insights and analyses are influencing vehicle design changes and helped determine which vehicles are best suited to the MRAP mission.

In October 2008, ARL began a high operational tempo to improve the IFK6 technology so that higher performance armors with no increase in weight could be inserted into the MRAP production scheduled for winter 2008.

As a result, ARL was able to introduce armor with increased performance and unprecedented weight reduction. ARL also developed specifications to procure advanced composites and used knowledge of international industrial capacity to guide the armor development.

These armor technologies were transitioned to TARDEC and the MRAP JPO. Expedient armor designs were implemented as add-on kits by government depots and on production lines by contractors in large quantities. By the end of FY08, these fielded armor systems had been proven successful in battle.

In the future, ARL will introduce far more advanced technologies that will greatly improve armor capabilities and maintain our edge against emerging threats.

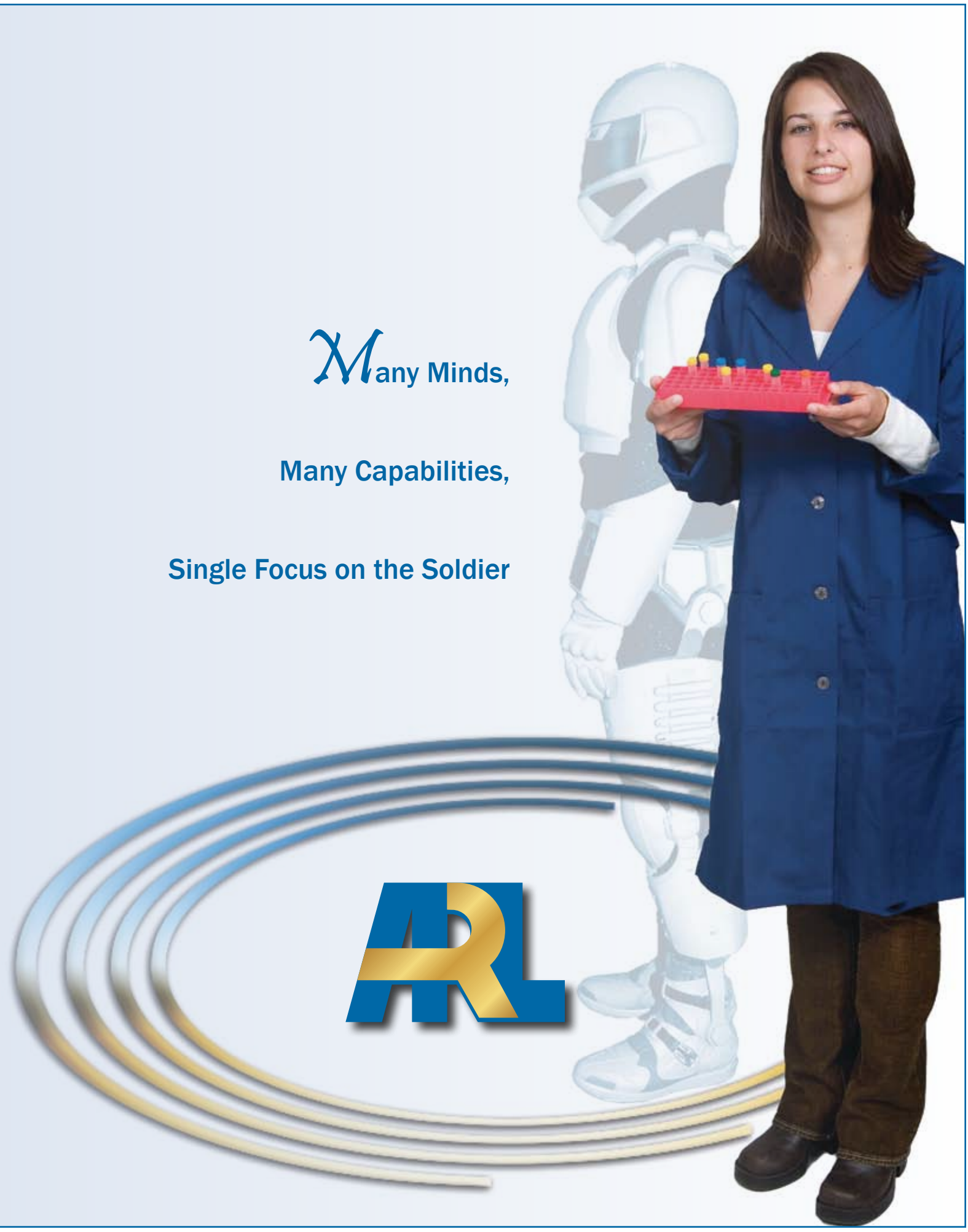
ARL's multi-disciplinary approach utilized our expertise in ballistics, materials, vulnerability analysis and human factors to successfully support the rapid acceleration of MRAP development and fielding.

From the Director

As a laboratory, we need to balance our investments in research and analysis in three areas: (1) maturing new technologies and performing responsive analyses for rapid insertion into Army acquisition programs by our customers, (2) translating new research and analysis capabilities into useful military technologies and applications for Army mid-term requirements, and (3) guiding our strategic investments in basic sciences, research, and analysis capabilities to meet the long-term operational needs of the U.S. Army.

Cutting-edge discoveries by our many technicians, scientists and engineers in the laboratory are essential to deliver decisive analyses, superior technologies and game-changing capabilities for future generations of Army Warfighters. Our strategic investments in talented and knowledgeable people, extramural relationships with academia and industry, and state-of-the art equipment and facilities are critical to ensure our continued support to the current and future Army. Of these investments, our many minds are critical to develop new knowledge and many capabilities for our single focus, the U.S. Soldier. As a laboratory, we must continually foster educational and professional opportunities for everyone–administrative personnel, technicians, scientists and engineers. In addition, we must also encourage U.S. students from middle school through post-doctorate programs to pursue science, mathematics and engineering fields. These students are critical to develop our next generation of cutting edge discoveries.

As we keep our eye on the future for the Army, we must build upon our laboratory's strengths in integrated applications of experimental methods, theories, and models. We must build upon our laboratory's endeavors in extramural basic research, protection, lethality, human dimension, survivability/lethality analysis, networks, sensors, power and energy and mobility. We must also expand our strengths to new multidisciplinary research and analysis challenges by undertaking promising new areas in materials, bioscience, neuroscience, systems of systems analysis, network science, electronics, power and energy, and autonomous systems technologies. In short, we must continuously transform to build on the excellence of our work over the past 16 years and meet the needs of the Army's next generation of Soldiers.


Many Minds,
Many Capabilities,
Single Focus on the Soldier
ARL

Glossary

AARL	Aeronautical and Astronautical Research Laboratory
AEC	Army Environmental Command
AFRL	Air Force Research Laboratory
AIRMICS	Army Institute for Research in Management Information, Communications, and Computer Science
AiTR	Aided Target Recognition
AMC	Army Materiel Command
AMCOM	Aviation and Missile Command
AMSAA	Army Materiel Systems Analysis Activity
AMRDEC	Aviation and Missile Research, Development and Engineering Center
ANL	Argonne National Laboratory
APG	Aberdeen Proving Ground
ARDEC	Armament Research, Development and Engineering Center
ARI	Army Research Institute
ARL	Army Research Laboratory
ARO	Army Research Office
ATC	Aberdeen Test Center
ATEC	Army Test and Evaluation Command
ATO	Army Technology Objective
BTRA-BC	Battlespace Terrain Reasoning Awareness-Battle Command
C	Celsius
C2Vs	Command and Control Vehicles
C4ISR	Command, Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance
CERDEC	Communications-Electronics Research, Development and Engineering Center
CISD	Computational and Information Sciences Directorate
CMOS	Complimentary Metal Oxide Silicon
CNO	Computer Network Operation
COMMS	Communications
CRADA	Cooperative Research and Development Agreement
CTA	Collaborative Technology Alliances
DARPA	Defense Advanced Research Projects Agency
DC-DC	Direct Current to Direct Current
DIA	Defense Intelligence Agency
DEA	Drug Enforcement Agency
DHS	Department of Homeland Security
DoD	Department of Defense
DOE	Department of Energy
DRI	Director's Research Initiative
DTC	Development Test Command
EAR	Environment for Auditory Research
ECBC	Edgewood Chemical Biological Center
ECP	Engineering Change Proposal
EMVAF	Electromagnetic Vulnerability Assessment Facility
EO	Electro-Optic
EPLRS	Enhance Position Location Reporting System
EUCOM	European Command
EVAF	Electronic Vulnerability Assessment Facility
FCS	Future Combat Systems
FCS MGV	Future Combat Systems Manned Ground Vehicle
FDC	Flexible Display Center
FUGS	Family of Unattended Ground Sensors
FUSL	Full-Up System Level
FY	Fiscal Year
G-1	Personnel and Administration (General Staff)
G-2	Intelligence (General Staff)
G-4	Logistics (General Staff)
G-6	Information Technology (General Staff)
GN&C	Guidance, Navigation and Control
GSF	Gross Square Feet
HBCU	Historically Black Colleges and Universities
HMMWV	High Mobility Multipurpose Wheeled Vehicle
HPCRC	High Performance Computing Research Center

HPM	High Power Microwave
HQDA	Headquarters, Department of the Army
HRED	Human Research and Engineering Directorate
IAT	Institute for Advanced Technology
ICB	Institute for Collaborative Biotechnologies
ICT	Institute for Creative Technologies
IED	Improvised Explosive Device
INSCOM	Intelligence and Security Command
ISN	Institute for Soldier Nanotechnologies
ISR	Intelligence, Surveillance and Reconnaissance
IWEDA	Integrated Weather Effects Decision Aid
JAYCEES	United States Junior Chamber of Commerce
JFCOM	Joint Forces Command
JIEDDO	Joint Improvised Explosive Device Defeat Organization
JMPO	Joint MILSTAR Program Office
JPEO-CBD	Joint Program Executive Office – Chemical Biological Defense
JPL	Jet Propulsion Laboratory
JPO	Joint Program Office
JTAPIC	Joint Trauma Analysis and Prevention of Injury in Combat
JTRS	Joint Tactical Radio System
M/PRF	Mobility/Portability Research Facility
MANET	Mobile Ad Hoc Network
MAST	Micro Autonomous Science and Technology
MAWRS	MRAP Armor Weight Reduction Spiral
MDA	Missile Defense Agency
ME	Micro Edition
MEDCOM	Medical Command
MEMS	Micro Electro Mechanical Systems
MHz	Megahertz
MI	Minority Institutions
MIT	Massachusetts Institute of Technology
MOUT	Military Operations in Urban Terrain
MRAP	Mine Resistant Ambush Protected Vehicle
MRMC	Medical Research and Materiel Command
MSRC	Major Shared Resource Center
MURI	Multidisciplinary University Research Initiative
NAVAIR	Naval Air (Station)
NEMS	Nanoelectromechanical Switches
NERF	Novel Energetics Research Facility
NIST	National Institute of Standards and Technology
NRC	National Research Council
NRL	Naval Research Laboratory
NSRDEC	Natick Soldier Research, Development and Engineering Center
OASA (ALT)	Office of the Assistant Secretary of the Army (Acquisition, Logistics and Technology)
ODT	Omni-Directional Treadmill
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
ONAMI	Oregon Nanoscience and Microtechnologies Institute
ONR	Office of Naval Research
OP	Outreach Program
ORNL	Oak Ridge National Laboratory
OTM	On-the-Move
PCSS	Photo Conducting Semiconductor Switch
PEO	Program Executive Office
PEO AMMO	Program Executive Office – Ammunition
PEO AVN	Program Executive Office – Aviation
PEO CBD	Program Executive Office – Chem/Bio Defense
PEO CS&CSS	Program Executive Office – Combat Support and Combat Service Support
PEO IEWS	Program Executive Office – Intelligence, Electronic Warfare and Sensors

Glossary

PEO Soldier	Program Executive Office – Soldier
PM	Program Manager
PM CAS	Program Manager – Close Air Support
PM FCS BCT	Project Manager – Future Combat Systems, Brigade Combat Team
PM NVRSTA	Program Manager – Night Vision, Reconnaissance, Surveillance and Target Acquisition
PM RUS	Project Manager – Robotics and Unmanned Sensors
PSI	Pounds per Square Inch
PZT	Piezoelectric Transducer
R&D	Research and Development
RAM	Radar Absorbent Material
RAPTR	Redstone Aviation Propulsion Test and Research
RDECOM	Research, Development and Engineering Command
RDEC	Research, Development and Engineering Center
RDT&E	Research, Development, Test and Evaluation
RE	Real-time Edition
REF	Rapid Equipping Force
RF	Radio Frequency
RMRL	Rodman Materials Research Laboratory
RPM	Revolutions Per Minute
SATCOM	Satellite Communications
SE	Standard Edition
S&E	Scientific and Engineering
S&T	Science and Technology
SEDD	Sensors and Electron Devices Directorate
SBIR	Small Business Innovation Research
SID	System Integration Domain
SIL	Systems Integration Laboratory
SINCGARS	Single Channel Ground and Airborne Radio System
SLAD	Survivability/Lethality Analysis Directorate
SLV	Survivability, Lethality and Vulnerability
SMDC	Space and Missile Defense Command
SOCOM	Special Operations Command
SPACE	Scalable Phase-locked Adaptive Communication Element
SPD	Supersonic Particle Deposition
SRW	Soldier Radio Waveform
STACA	Science, Technology and Acquisition Corps Advisor
STARS	Science and Technology Academic Recognition System
STI	Strategic Technology Initiatives
STTC	Simulation and Training Technology Center
STTR	Small Business Technology Transfer Program
SWE	Society of Women Engineers
TARDEC	Tank Automotive Research, Development and Engineering Center
TBO	Time-Between-Overhaul
TESF	Tactical Environment Simulation Facility
TFT	Technology Focus Team
TPA	Technology Program Objective
TRADOC	Training and Doctrine Command
TSA	Technical Support Agreement
UAV	Unmanned Aerial Vehicle
UCSB	University of California at Santa Barbara
UGS	Unattended Ground Sensors
USACE	United States Army Corps of Engineers
USMA	United States Military Academy
USMC	United States Marine Corps
VAPP	Very Affordable Precision Projectile
VIMF	Vertical Impulse Measurement Facility
VTD	Vehicle Technology Directorate
WEL	Wireless Emulation Laboratory
WMRD	Weapons and Material Research Directorate
WSMR	White Sands Missile Range

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